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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 479

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER May 31, 1917

NURSERY PRACTICE ON THE NATIONAL FORESTS

By

C. R. TILLOTSON, Forest Examiner

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NURSERY PRACTICE ON THE NATIONAL FORESTS.[1]

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INTRODUCTION.

Each year about 10,000,000 forest-tree seedlings or transplants are required for the reforestation operations on the National Forests. The stock supplied for these operations must be of the proper size and species, of high grade, and available for use on very short notice. Furthermore, production of the stock under seasonal conditions corresponding as closely as possible to those at the planting site is desirable. In order that these requirements may be met and that at the same time the stock may be produced at a low cost it is necessary not only that the nurseries be properly located and of the right size, but also that efficient and economical methods of nursery practice be employed.

FACTORS INFLUENCING SELECTION OF A NURSERY SITE.

Choosing a site for a large nursery is difficult, especially in a mountainous country, where all of the conditions favorable to nursery operations are seldom encountered on one area. The principal

[1] This bulletin represents the results of the study and experience of many different members of the Forest Service. The author's part has been to compile, weigh, and harmonize these results. The collection of forest-tree seed and field seedling and planting are covered in Bulletin No. 475 of the U. S. Department of Agriculture, "Reforestation on the National Forests."

NOTE.—This bulletin should prove of interest and value to all who are engaged in nursery work with forest trees.

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factors to be considered are: (1) The water supply; (2) the soil; (3) the amount of land available; (4) the exposure and slope of the site; (5) its accessibility; (6) the species of stock to be raised; (7) the nature of the surroundings; (8) the cover of the site; and (9) the climate.

WATER SUPPLY.

Plants grown in nurseries are subjected to unfavorable conditions of crowding and often of climate not encountered under natural conditions. Yet an effort must be made to keep the mortality rate as low as possible and to produce good stock for field planting. For these reasons it is essential in selecting a site for a nursery to choose one where there is an abundant supply of water.

The amount of water necessary depends upon the size of the nursery and its possible future extension, the method followed in watering, the amount and distribution of rainfall, and the character of the soil. A very porous, well-drained soil will require a greater supply of water than a heavier, more retentive one. If open-ditch irrigation of the beds is practiced a greater supply will be necessary, because of seepage, than if the water is conveyed in pipes and distributed by sprinklers. If the rainfall were evenly distributed and sufficient for all needs of the plants it would, of course, eliminate the necessity of a water supply. This condition seldom exists. While abundant precipitation may occur during a portion of the growing season, there is almost certain to be a dry period when artificial watering will be necessary and when a supply as abundant for the time being as if the whole year were dry will be needed.

In every case the amount of water available during the period of low water and, if possible, the minimum flow during extremely dry years should be ascertained. Where water is in urgent demand for irrigation purposes, it is vitally important to know whether there is, during dry seasons, sufficient unappropriated water in a stream under consideration, and what the State laws are regarding its use.

At the Savenac Nursery, where ditch irrigation is practiced, at the Bessey Nursery, where flooding of the beds is practiced, and at the Wind River Nursery, where garden sprinklers are used entirely, about 4,800, 225, and 75 gallons of water per minute are available, respectively. The yearly capacity of the nurseries is 4,000,000, 2,000,000, and 2,000,000 plants, and the areas actually occupied by nursery stock are about 15, 3, and 4 acres, respectively. Except possibly in the case of the Savenac Nursery, the amount of water available is not more than is desirable for successful nursery operations.

Where it is intended to use garden sprinklers, it is well to know that, under good water pressure, either the rotary or stationary type of these sprinklers throws from 4 to 6 gallons of water per minute.

When the spray falls in a 10-foot radius, this equals from 1.3 to 1.9 inches of rainfall per hour. It may occasionally be necessary to use 10 or 12 sprinklers at one time, which means that there must be available at least from 40 to 75 gallons of water per minute.

SOIL.

In choosing the location for a nursery, soil possessing the best chemical and physical properties should be selected. Forest Service experience has not indicated that it should resemble the soil of the planting site, especially where that is poor. Plants grown in poor soil, particularly dry soil, are forced to extend their roots in search of moisture; and when such plants are removed from the nursey the fine feeding roots are almost certain to be cut off and the stock rendered less fit for field planting. Thrifty plants with a normal root development grown on good soil generally offer the best chance for success.

The soil should be sufficiently fertile; but desirable physical qualities, such as moderate freshness, friability, and depth, are of more importance than chemical ones, since the latter may be more easily changed through the use of fertilizers than the former.

A soil with a sandy foundation, particularly a sandy loam, is better suited for nursery operations than one with a clay or lime foundation (see Pl. I). The latter dries out and warms up slowly in the spring, delaying nursery operations and retarding the growth of the plants; it freezes and heaves much more decidedly than the former; it is more difficult to work in plowing, cultivating, and transplanting operations; the roots skin more when the trees are dug; it forms a hard surface and cracks upon drying; seedlings sometimes have difficulty in pushing through it; the development of the fine, lateral roots is not so good as in lighter soils; and weeds obtain a much firmer foothold. On the other hand, a soil extremely light, sandy, or loose should be avoided because of the rapidity with which it dries out, the too extensive and undesirable root development which it fosters, and the danger of general unthriftiness of the plants.

If the surface soil is a good, fairly moist, retentive, sandy loam, the deeper it is the better. Where it is deep there will be an abundant supply of fertility upon which to draw, the infertile subsoil will not be disturbed by plowing and mixed with the other soil, and the soil conditions will be ideal for the development of excellent stock. A very desirable combination is good, porous surface soil from 3 to 4 feet in depth, underlaid by a more retentive subsoil. Such a surface soil is of sufficient depth to allow the necessary drainage; and as moisture is needed it can be drawn from the retentive subsoil

by capillarity. A subsoil of hardpan is to be avoided because it does not allow good drainage and the moisture retained may cause souring of the soil and excessive freezing and heaving.

AMOUNT OF LAND AVAILABLE.

The future development of a nursery can seldom be forecasted. After the nursery is established the location, soil, or some other feature may be found to make it especially suitable for the growing of certain species of trees; the stock may have to be retained in the nursery longer than was anticipated; wider spacing may prove advisable; longer rotations of crops may become necessary; or a portion of the area may have to lie fallow longer than was expected. Any of these conditions will make extension of the nursery area desirable. A location should be chosen, therefore, where there is an additional contiguous area of good soil lying in such a position that the watering system can be readily extended to it.

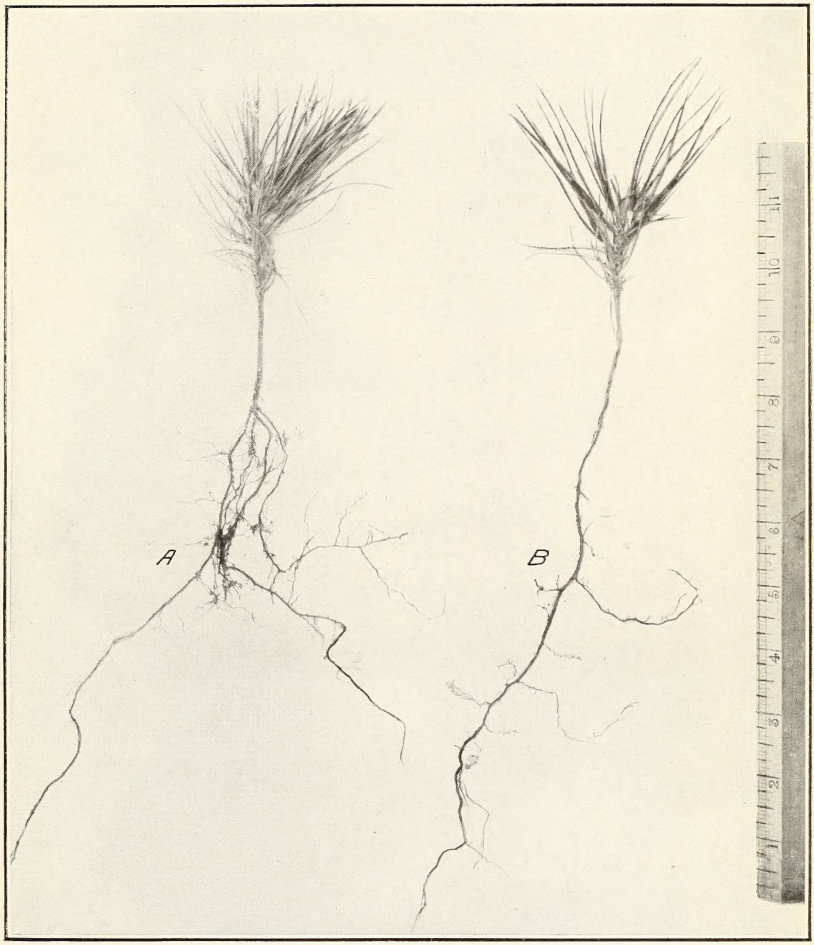
SLOPE AND EXPOSURE OF SITE.

The nursery site should be as level as possible, because of the danger that the soil on a slope will wash during severe rains or artificial watering. Of course, grades can be lessened by terracing. This is expensive, however, and on terraced areas plowing and harrowing are carried on with difficulty, and protection ditches are almost indispensable. Under no circumstances should the slope exceed 5 per cent, and even such a slope is excessive where irrigation is to be practiced.

On slight slopes the exposure is of little import. There is but little difference in the temperature, frost danger, or length of growing season of the different aspects. On steeper slopes, north, northeast, and northwest aspects are more suitable for nursery purposes than south and west, because of the smaller range of temperature. Frost danger is greater on the south and west slopes than on the others, because the plants normally start growth sooner and continue it later. Alternate freezing and thawing, which causes heaving, is more decided on south and west slopes than on the other three. So-called frost holes, or depressions in which the air drainage is poor, and narrow valleys or canyons, should be avoided entirely because of frost danger. In general, a higher location should be given preference over a lower one.

ACCESSIBILITY.

The relative importance of accessibility to base of supplies and labor or to planting sites depends upon whether the nursery is large or small. If it is small and the amount of labor and supplies neces-



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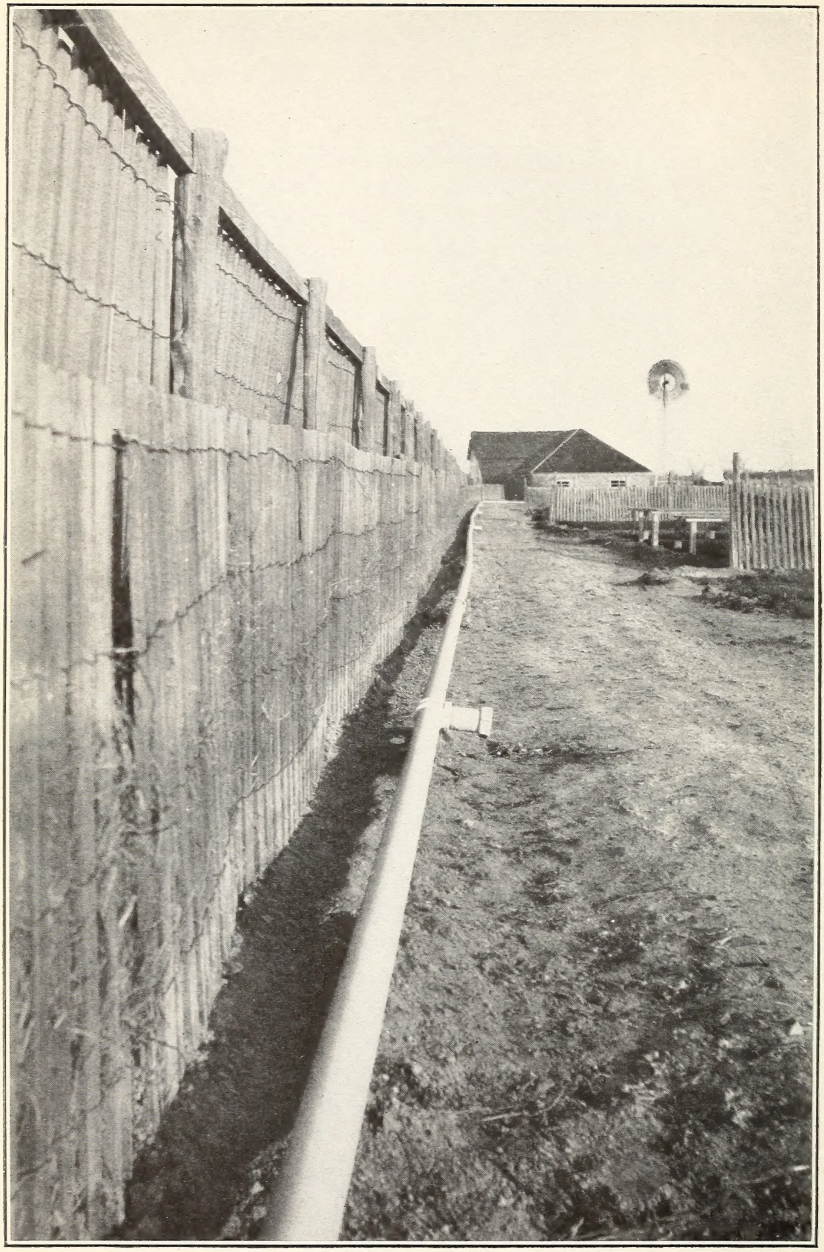
COMPARISON OF SEEDLING STOCK GROWN UNDER DIFFERENT SOIL CONDITIONS.

Note the difference in root development. *A. Pinus ponderosa* 2-0 Black Hills seed grown in light sandy soil. *B. Pinus ponderosa* 2-0 Black Hills seed grown in heavy clay soil.



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WATER-PIPE LINE 4 INCHES IN DIAMETER, FOR FLOODING TRANSPLANT BEDS, AND SLATTING FENCES USED FOR WINDBREAKS, BESSEY NURSERY.

sary is not great, it should be located as near the planting site as circumstances will permit. At a large permanent nursery, the initial as well as the regular yearly work necessitates the employment of a considerable number of laborers, the purchasing and hauling to the nursery of a large amount of material and supplies, and the hauling of the nursery stock to town for shipment. Accessibility to planting sites is not, accordingly, so important—though it is important—as location near a central shipping point where labor and supplies are readily available.

SPECIES OF STOCK TO BE RAISED.

In fully equipped nurseries, moisture and temperature conditions can be so controlled that danger from drought, intense heat and cold, low humidity, and early or late frosts is partly eliminated; yet if possible, the climatic requirements of the principal species to be produced should be given consideration in choosing the site. If western yellow pine is to be the principal species, preference should be given to sites well within the low altitudes. If, on the other hand, Engelmann spruce or lodgepole pine will make up the greatest proportion of the nursery stock, preference should be given to the sites at higher altitudes. The natural common occurrence of a species in a certain region is an unfailing indication that both soil and climate are well adapted to its growth. Production will usually be attended by fewer difficulties and losses at nurseries located within such a region than elsewhere, although there have been some instances where this has not seemed entirely true. Furthermore, less watering and shading may be necessary and protection against frosts and winter killing uncalled for, so that it will be possible to produce a high grade of stock at less cost.

NATURE OF THE SURROUNDINGS.

The surroundings have a minor effect upon nursery operations through their influence upon the weed problem, protection, shading, and watering. On old clearings, old burned-over areas, or abandoned fields, the conditions are particularly suited to the growth of weeds. At nurseries situated in such places it will usually be necessary to fight weeds continually. Such locations should be avoided if others fully as good in the more important considerations can be selected. There is the objection to having trees in the immediate vicinity of a nursery that they cause snowdrifts and retard melting of the snow in spring. It is possible also that they impede the circulation of air and thus subject the nursery stock to greater frost danger. Furthermore, excessive side shade from timber sometimes

keeps a nursery too cold and damp for the best development of the stock.

In Europe it is considered advisable to take advantage of locations where shade and protection against wind are afforded by old stands on the south and west sides. For species especially susceptible to heat or frost, such as spruce and fir, this side protection is considered especially desirable. Where the planting stock is of light-loving species, such as pine and larch, there should not be enough shade to be harmful. The size of a large nursery will eliminate the possibility of side shade for all the beds; but this will not necessarily be a disadvantage, because, usually, shade will not be desirable for all the species grown. All the beds, however, may be protected from hot and cold winds, making less watering and possibly less artificial protection necessary.

COVER OF THE SITE.

The growing cover of a site serves as a criterion of the quality of the soil, such as its fertility, acidity, or alkalinity, and normal moisture content. It also has an important bearing on the cost of putting the ground into condition for nursery purposes, the subsequent work which may be necessary, and the effect of the preliminary work upon the soil itself.

Dead and down logs and old stumps or a large amount of rock will necessitate expensive clearing operations. Where the stumps are large and numerous, as in Pacific coast Douglas fir cuttings, and the amount of down timber considerable, the cost of clearing and putting the ground into shape for nursery operations may amount to $200 or $300 per acre. This expense is not the only bad feature. Even after careful clearing and working up of the ground additional rocks, pieces of roots, bark, and twigs will be encountered for years to come. In removing rocks and stumps, moreover, the subsoil is thrown out on the surface, and being of inferior quality in most cases, gives rise to infertile patches throughout the nursery on which the growth of plants is poor. Besides when the stumps and logs are being burned the humus is also burned and the soil made poorer in quality. The inadvisability of choosing a rocky area or one covered with stumps is apparent unless other factors offset these disadvantages.

Too much emphasis, however, should not be laid upon the difference in the initial cost of soil preparation. Often the fact that timber has grown upon a site is a strong indication that after clearing the ground will be well suited for nursery purposes. While the cost of putting a treeless area into shape may be less, the site may not be so well suited for growing trees.

CLIMATE.

If possible nurseries should be located where the climatic conditions are very similar to those of the planting sites. Nursery stock will then be in a dormant stage in the spring or fall when planting should be done. Where climatic conditions are not similar, it often happens that in the spring the nursery stock must either be shipped while the planting site is still covered with snow or else held at the nursery, where it is likely to start growth; or it may be that the planting site will be free of snow and in the best condition for planting before the plants can be removed from the frozen or snow-covered beds of the nursery. In the fall the plants may be still in an unhardened condition at the time when planting operations should be conducted.

Regions of excessive winter winds where a snow cover does not remain should be avoided because of the danger of winter killing unless artificial mulching is practiced. Mulching is expensive, and the mulch affords a refuge under which rodents may work and damage the stock.

Regions of excessive rainfall, particularly if the soil is a cold one, are not well suited for nursery purposes. In such regions weeds are more numerous than where the climate is drier, moss and algæ collect on the nursery beds, the stock is less sturdy, nursery operations are impeded, and the number of species which can be successfully grown is smaller.

SIZE AND ARRANGEMENT OF NURSERY.

There are two general types of Forest Service nurseries: (1) The small nursery of a capacity ranging up to 200,000 plants annually, usually located at a ranger's headquarters and designed for the production of stock for planting only on the forest on which it is situated; and (2) the large nursery established to produce stock for planting a group of neighboring forests which have similar vegetal conditions.

The relative merits of small and large nurseries have not been finally determined; each possesses certain advantages over the other. Desirable sites of a suitable size for small nurseries are more plentiful than those for larger nurseries; the available water supply need not be so great; and permanent improvements in the nature of fences, water system, and buildings need not be so extensive. There is a decided advantage in growing plants near the areas where they are to be used; the stock is on hand when wanted; a part of the expense of packing and shipping is avoided, and retention by the roots of a part of the nursery soil, which would be shaken off in transportation, is permitted. Insect or fungous attacks in a small nursery can

not, in the aggregate, produce such disastrous results as in a large one. Furthermore, the time suitable for field planting can be utilized more readily with locally grown stock. Trees raised in nurseries at a lower elevation, for example, may begin vegetation before conditions on the planting site permit setting them out, and the best time for planting a warm, early site may pass before stock can be furnished from a nursery in a colder situation. On the other hand, because of the closer and more efficient supervision in the large nurseries, as well as better facilities for tending the stock, a greater proportion of the plants normally survive to the age of field planting, and the better care given the stock results in its being more fully developed and, other conditions being equal, more able to succeed under field conditions. The concentration of the work at large nurseries makes for efficient management, good stock, and low cost of production.

A central nursery should have a capacity of at least a million plants. This is desirable as a matter of economy, for the larger the nursery the more opportunity there will be for intensified work, the systematizing of each operation, and regular supervision. By these means the cost per thousand plants may be reduced; three or four million seedlings can be grown at a lower cost per thousand than one or two million. A large capacity is desirable for two other reasons besides the economy that may be effected: It is an insurance against a shortage of plants due to unforeseen losses, and heavy grading is possible in well-stocked nurseries, so that in each case very nearly the class of stock required may be furnished.

The actual area of a nursery is determined by the output that is desired, the species, the area occupied by paths and roads, the spacings, the class of stock produced, and the practice followed in the rotation of crops. Possible rotation of crops being disregarded, the following table indicates the area, exclusive of paths and roads, necessary for the growing of 1,000,000 seedlings and transplants yearly.

TABLE 1.—*Seed-bed area*[1] *in square feet, necessary to produce 1,000,000 seedlings yearly.*

Length of time in seed beds.	Number of seedlings per square foot.										
	50	75	100	125	150	175	200	225	250	275	300
	Area in square feet.[2]										
1 year	20,000	13,333	10,000	8,000	6,667	5,714	5,000	4,444	4,000	3,636	3,333
2 years	40,000	26,667	20,000	16,000	13,334	11,428	10,000	8,888	8,000	7,272	6,666
3 years	60,000	40,000	30,000	24,000	20,000	17,142	15,000	13,332	12,000	10,908	10,000

[1] Add 25 per cent in seed beds and from 10 to 20 per cent in transplant beds to allow for losses.

[2] 1 acre=43,560 square feet.

TABLE 2.—*Area*[1] *of transplant beds, in square feet, necessary to produce 1,000,000 transplants yearly.*

Length of time in transplant beds.	Spacings, in inches, in transplant beds.			
	1 by 5.	1 by 6.	1 by 8.	3 by 4.
	Area in square feet.[2]			
1 year	34,722	41,666	55,555	83,333
2 years	69,444	83,332	111,110	166,667

[1] Add 25 per cent in seed beds and from 10 to 20 per cent in transplant beds to allow for losses.
[2] 1 acre=43,560 square feet.

Because of differences in topography, in the characteristics of the soil, and possibly in the requirements of the species, the form of a nursery will vary as the location varies. Generally speaking, an area either square or rectangular, with the two adjoining sides not differing much in length, is the best form. The topography of the area often makes it impossible to lay out a nursery according to a preconceived plan. The necessity of following the base of a hill or avoiding rocky patches of ground may make regularity of outline inadvisable. The nursery should not be made up of a number of small individual areas. They may not admit of plowing and cultivating and may necessitate preparation by hand, a slow and expensive operation. Two or three larger areas widely separated do not make a good nursery because of the time lost in passing from one section to the other.

If uniform soil conditions exist throughout the nursery, there need be little choice as to the location of seed and transplant beds, except as a matter of convenience. Where uniformity does not exist, it is advisable to locate the seed beds in the portion having the better soil. Seedlings come up in close stands in the seed beds, so that they make greater demands upon the soil and are more subject to ill effects from poor soil than transplants, which have better conditions of growth. Where differences in soil, protection, or other conditions exist in the nursery area, it is also desirable to arrange the beds so that the hardiest species will occupy the most trying situations. Thus western yellow pine can be grown to better advantage in stony portions or those most likely to dry out rapidly than can spruce, and spruce and fir should be grown where they would have the advantage of any natural shade. This phase of nursery practice is not of great importance, however, since the conditions can be so changed artificially that any of the species can be made to thrive in any part of the nursery. Where it is necessary to shade either the seedlings or transplants, the beds should have their long axes east and west.

The water system, after it is established, will determine to some extent the arrangement of the beds. A row of hydrants will fix the location of a path, and to facilitate watering at least the transplant beds should be laid out with their long axes at right angles to this path or row.

OUTFIT.

WATER SYSTEMS.

The initial cost of a water system is high, and once a system is installed it can be changed only with considerable difficulty and expense. A satisfactory system will save many hitches and delays and in the end will effect great economy. It is desirable, therefore, to plan carefully before its installation and to have in mind its really essential and most desirable features. These will be enumerated under the discussion of the different kinds of systems. There are two principal types of systems in use in nursery operations: (1) The irrigation system, and (2) the sprinkling system.

IRRIGATION SYSTEM.

In the irrigation system the water is brought to the nursery area either in a ditch or flume which taps a supply at an elevation somewhat above that of the nursery, or it may be pumped from a lower level to that of the nursery. It is then distributed to the plants either by means of numerous small ditches from 2 to 3 feet apart having so slight a gradient that the water flows very slowly, or by flooding entire beds. When water is diverted from a stream desirable features of an irrigation system are a good, substantial dam at the point of diversion of the water, a head gate which permits perfect control of the water entering the ditch, and a clay-lined ditch or a flume to convey the water to the nursery. A flume or water pipe is somewhat preferable to an open ditch. The gradient of the main ditch or flume will depend upon the velocity desired and the cross-sectional area of the channel. At the Savenac Nursery the main ditch, which is slightly over a mile in length, has a fall of 6 feet. The gradient of the small ditches which convey the water to the plants throughout the nursery should not, in heavy soils, exceed $1\frac{1}{2}$ inches, or, in light, porous soils, 3 inches per 100 feet.

When water is pumped from a lower level directly to the nursery for irrigation purposes, the prime essential in addition to that of gradient is that there be pumps of sufficient capacity to furnish all the water necessary while the operation is in progress. At the Bessey Nursery three 5-horsepower gasoline engines and centrifugal pumps are used to pump water from the river into a 4-inch main

pipe line which runs along one edge of the nursery. (See Pl. II.) From this pipe it is distributed to the beds through 6-inch canvas hose, flooding being practiced for transplant beds and for the seed beds after germination is completed.

SPRINKLING SYSTEM.

In the sprinkling system the water is conveyed to and through the nursery by a system of pipes and applied to the plants ordinarily by the use of garden sprinklers. Where it is practicable, a gravity pipe-line sprinkling system in which water is diverted from a spring or stream at a higher elevation and thence conveyed directly to the nursery is the best type because it is the simplest. A system with a tank or reservoir above the level of the nursery to which water is pumped and then piped to the nursery may in some cases be the most practicable one. A tank or reservoir may sometimes be necessary, even with a gravity system, to provide for storage of water to meet the needs of the nursery when heavy watering is practiced.

In planning a sprinkling system the length of hose to be used should first be decided. The most convenient length is 50 feet. Greater lengths are cumbersome; shorter lengths necessitate a too frequent change of faucets. As a hose should reach half way between parallel lines of pipes, it follows that adjacent pipe lines should not be farther apart than 100 feet. Given two faucets 100 feet apart, it is clear that a 50-foot hose will convey water in a line with them over a distance of at least 190 feet. This allows only 45 feet for the length of the hose, the assumption being that a portion of its length will be taken up by curves at the faucet and nozzle. Keeping on a path, a man, hose in hand, can conveniently water a strip only about 15 feet wide on either side of it. This indicates that the paths from which the watering is to be done should be 30 feet apart and that there should be a faucet at each path. Thus the sections of beds should be 30 feet wide throughout and of any desired length up to 100 feet. For a sprinkling system of watering, this is believed to be a very economical arrangement of pipe lines and faucets. If a shorter hose were used it would be necessary to have the main pipe lines closer, necessitating more pipe and more labor for installation. The use of a longer hose would mean less pipe, but much additional time and labor in handling the hose. The increased weight of longer hose is not of particular significance, but the care necessary to prevent its dragging across the beds and bending and breaking the plants is much greater in long than in short lengths.

From each faucet of a system so installed an area of 3,000 square feet can be watered by means of a nozzle. If lawn sprinklers are used the spacing of the faucets on each pipe line should be regulated by the distance to which the spray can be thrown when several sprinklers are in use. Twice this distance will determine the spacing. Thus if the spray can be thrown in a radius of 10 feet the faucets should be 20 feet apart.

The pipe should be sunk deep enough to allow the use of plow and harrow in preparing the ground; and where there is need for water all winter, the system should be buried deep enough to avoid the danger of freezing.

The longer the pipes the smaller their diameter, and the less the head of water the greater is the decrease in flow through friction. It follows that to obtain the same flow per unit of time the head of water must be greater when small than when large pipes are used, and that with a given head and quantity the greater volume of water will be available for use if it is conducted to and through a nursery in large pipes. It is often difficult to control the length of the pipes and the head of water. The size of the pipe used, however, is entirely within control. In order to secure sufficient pressure to run 10 or 12 sprinklers at the same time there should be a head of water not less than 50 feet; the main pipe should be 3 or 4 inches in diameter (the latter is preferable); and the laterals and standpipes should be 1½ or 2 inches in diameter. One system which embodies these features has over 4,000 feet of main-line pipe, but at its lower end it carries 75 gallons of water per minute.

To facilitate its cleaning out, a water reservoir should have an outlet besides that of the distributing pipe line. To prevent sand or gravel from getting into the system and clogging nozzles or sprinklers, the pipe at the intake should be covered with both a coarse and a fine screen.

There should be one gate valve next to the reservoir, one on the main pipe just before it reaches the nursery area, and one at the junction of each lateral with the main pipe. The pipe line should have union connections at intervals of approximately 100 feet and at the junction of branches. These will make it unnecessary to dig up the entire line when there is a part to be mended. There should be a plug or preferably a gate valve at the lower end of the main and of each branch of the pipe line. These will permit the washing out of the pipes in case they become clogged or obstructed, and also their draining for the winter. All of the unions and any of the other important parts of the underground pipes should be clearly marked on the ground itself in some manner, such as by boxed openings or slightly projecting stakes. Finally a very careful diagram of the system, on which all of its parts are clearly indicated,

should be drawn to scale. A system embodying these desirable features is shown in figure 1.

Cost of pipe.—While the costs of pipe vary, some of the prices paid at Forest Service nurseries are cited, simply to show the relative value of different types:

	Cents per foot.
6-inch Douglas fir wooden pipe[1]	17¼
4-inch Douglas fir wooden pipe	13½
4-inch black iron pipe	43½
2½-inch galvanized-iron pipe	25
2-inch galvanized-iron pipe	18
1¼-inch galvanized-iron pipe	12
1-inch galvanized-iron pipe	8

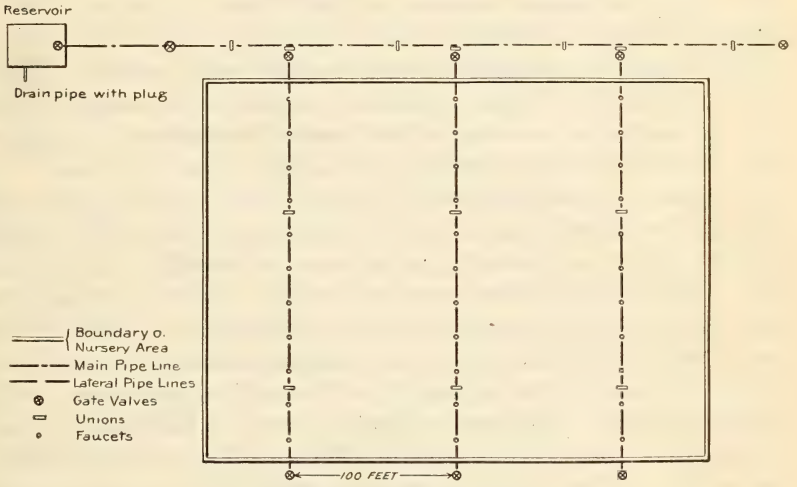

FIG. 1.—Diagram of a water system.

COMPARATIVE MERITS OF IRRIGATION AND SPRINKLING SYSTEMS.

In general, irrigation is not so satisfactory as a piping system. It has some commendable points and others which are objectionable. It does not require so large an initial outlay as a sprinkling system; there need be very little head to the flow of water; in subirrigation by ditches heavy soils do not tend to bake so much as when sprinkled; possibly a greater area can be covered per day than by sprinkling, and the water which comes in open ditches usually is warmer than that coming through pipes, which is a desirable feature. On the other hand, to irrigate effectively there must be very little slope to the land and the area must be very evenly graded; ditch irrigation necessitates frequent paths, and consequently a much larger area for the production of stock, with all that it entails in prepara-

[1] Douglas fir wooden pipe has given excellent satisfaction where used. Galvanized-iron pipe wears better than black iron pipe.

tion, fertilization, weeding, and cultivation; the main ditch may silt up and have to be dug out each spring and the laterals have to be entirely reconstructed each time the area is replowed; it takes a more experienced man to water by irrigation than by sprinkling; a considerable number of plants are covered in digging out and filling up a ditch to divert the water from one ditch to another; transplants can not very readily be watered immediately after being set out; all plants are not watered evenly; baking is worse when flooding is practiced on clay soils than under any other system; and it requires more water for each operation than does sprinkling.

INCLOSURE FOR NURSERY AREA.

At every permanent nursery a good fence is needed, and all nurseries subject to damage through grazing by domestic stock or by deer must be adequately fenced against such animals. Where rabbits abound it will often be desirable to protect the nursery against them by meshed wire screen at the base of the fence or by a woven wire fence whose lower mesh is small enough to exclude them.

If a nursery is subjected to the action of heavy winds which bend, whip, or break the plants or shift a light soil so as to cover a portion of them, or dry out the soil, a windbreak is desirable. A slat fence 5 or 6 feet high will afford some protection. A very effective windbreak is made by nailing parallel rows of slatting on both sides of a row of posts and stuffing the space between with hay. Living windbreaks of trees or shrubs also afford protection and where needed should be grown. The trees or shrubs chosen for the purpose should be those of a compact, bushy habit which are known to be hardy in the locality. They should be planted from 25 to 50 feet from the nursery area. If immediately adjacent, they do considerable damage to the nursery stock growing within their root zone.

NURSERY BUILDINGS.

At large nurseries there will generally be needed several nursery buildings, a house and woodshed for the man in charge, a barn, a packing shed, and a storehouse. The storehouse will serve as a storage place for seed supplies, tools, stakes, hose, lath shade frames, seed-bed frames of the knock-down type, and any other equipment. It should be located as near the nursery as possible. The packing shed should be partly open to the south and should be supplied with packing-box material, moss, burlap, nails, cord, labels, and paint.

At nurseries so far removed from town that it will be necessary at times to feed and house a working crew, a cook house and bunk house will be necessary. The bunk house should be furnished with a heating stove and the cook house with a large cooking range, a complete set of cooking utensils and dishes, good working benches,

a sink and drain, running water if possible, a hot-water barrel, shelves, and a long dining table with benches. A small storeroom for supplies and a bedroom for the cook and cookee should be partitioned off.

NURSERY EQUIPMENT.

Considerable equipment is necessary in a nursery. The loss of time and increase in labor and trouble caused by insufficient equipment will ordinarily amount in a short time to more than the cost of an adequate supply. The equipment is not the same in all nurseries; but that generally needed and its current cost in 1913 is indicated below:

Equipment.	Cost.
Team	$350–$400
Box wagon	75– 100
Plow, 14-inch	16.50
Harrow	18.00
Axes with handles:	
Single bit	1.75
Double bit	2.00
Shovels	1.25
Spades	1.25
Rakes	.75
Mattocks with handles	1.25
Picks with handles	1.25
Sledge No. 6	1.10
Post-hole digger	1.75
Crowbar, per pound	.08
Forge	10.00
Anvil, per pound	.13
Tools for forge, per set	12.00
Hoes	.75
Pipe tools:	
Threader and dies for 1-inch and 2-inch pipe	7.50
Pipe vise	2.25
Stillson wrenches, 14-inch	.65
Stillson wrenches, 18-inch	.90
Hammer	.75
Carpenter's saw	2.00
Steel square	1.50
Chisels	.50–1.50
Brace	1.25
Set of bits for brace	4.50
Bench screw for vise	.75
Hose, per linear foot	.12
Mole trap	1.25
Gopher trap	1.25
Mouse trap	.05
Nails, per pound	.05
Screws (price varies)	.....
Planting boards (price varies)	.50–2.50
Heavy flax twine, per pound	.35
Wheelbarrow (steel)	7.50
Scale for weighing seed	10.00

In addition, it is always well to have on hand a little lumber—dimension stuff, planks, and boards.

NURSERY OPERATIONS.

NURSERY SUPERVISION.

The measure of success in nursery practice is the character of the stock produced and its cost. The various operations should therefore be under the supervision of an efficient executive or foreman, one who is thoroughly practical, a close observer, constantly

alert to improve methods in the ordinary routine, and fully alive to the desirability of reducing costs of operation and overhead charges. It is desirable that he have a knowledge of plant physiology and pathology, for this will enable him to note quickly imperfections or disease in his stock and to seek methods for improving its quality or health.

INITIAL PREPARATION OF NURSERY SITE.

On a site which has already been cleared or is free of all stumps, logs, and woody growth, the first step in preparing the ground is to remove the litter, rocks, and pieces of roots. The surface soil should be thoroughly hand raked and rubbish carted away; the area should then be plowed and harrowed very thoroughly. Where there is a grass cover it should be scraped off close and burnt to ashes after the sod is thoroughly dried; or better, it may be plowed under and the area devoted to field crops for a year or two until the sod is thoroughly decomposed. Piles of brush should not be burned on the nursery area because deterioration of the soil results.

Experience has proved that plowing and replowing and harrowing and reharrowing, amply pay for themselves in the resulting condition of the area. Rocks, roots, and trash which would interfere with the nursery operations are not only brought to the surface and removed, but hollows are filled in and elevations cut down until the whole surface is brought to an even grade. The initial plowing and harrowing must be more intensive than those of after years because of the greater amount of rubbish present and the roughness of the land. Heavy soils, fall plowed and left rough, are much mellowed and improved by the action of the frost and are in a better state to absorb and retain the winter moisture. Unless replowed in the spring, however, they are packed and hard to work. Spring plowing and harrowing puts a soil in excellent condition for working; but after transplanting operations are finished the soil may settle and leave the plants sticking too high out of the ground. The combination of fall plowing with cross plowing and harrowing in the spring is undoubtedly best, provided the soil can be watered and settled somewhat before transplanting begins.

The seed-bed area should be further prepared with a shovel or garden fork, the lumps of earth mashed, and then finely pulverized by raking. In either plowing or spading the soil should, if possible, be stirred to a depth of a foot. Very shallow cultivation may result in shallow root development, heaving, and poor plant growth through drying out of the soil. Deep cultivation involves the risk of bringing to the surface the poorer, less fertile subsoil, in which plants do not develop properly.

PREPARATION OF SEED BEDS.

Where damage from rodents or birds need not be guarded against the seed beds may be of any desired size. They should be staked off uniformly and with mathematical precision. This will make calculations easy and will make possible the employment of uniform methods in subsequent work. A 4-foot width facilitates sowing, covering, and weeding operations. Forty inches has been found to be a desirable width where burlap is used as a cover. Where damage from rodents or birds is possible small beds 4 by 12 feet are desirable, because they are easily protected by the use of the screened frames, to be discussed later.

To promote capillary action and avoid uneven settling of the soil, particularly where the soil is light and sandy, the beds should either be rolled with a heavy hand roller or thoroughly watered before the final leveling. The leveling and smoothing of the surface is done with a rake and should be thorough. It will help in securing an even covering of the seed and uniform germination, for an irregular surface is often responsible for seedlings appearing thickly in one spot and thinly in another.

At one of the California nurseries a special method of leveling has been used. A frame 4 by 12 feet, inside dimensions, is constructed of 1 by 4 inch material, the boards resting on edge. This is sunk about 1 inch into the beds that have been spaded and raked. A section 3 inches wide by 6 inches long is cut out of the lower edge of each end of a board 1 inch by 4 inches by 5 feet, which results in the shape shown in figure 2. The portion of the board which is 4 feet long and 3 inches deep is intended to fit within the 4-foot frame, the 6-inch ends resting upon the sides of the frame and serving as handles. The appearance of the frame and board in operation is shown in figure 2. The board, which is called the "planing board," is drawn the length of the bed with the projecting inner 4-foot portion sweeping over the loose soil. As the board is drawn along it may be necessary to fill in with soil any low places in the bed in front of it. The surface of a bed thus prepared will be smooth and ready for sowing.

A slight modification of the apparatus appears to be more practical. The frame need not be sunk into the bed, but may be rested on the surface of the soil. The projecting portion of the planing board will then have to be as deep as the frame itself. Three-inch material, stiff enough to retain its shape, is wide enough for the construction of the frames. At the Wind River Nursery, where this system is followed, the lower sill of the shade frame is used instead of a special frame.

On first-class nursery situations the drainage of the seed beds will not need consideration. If the drainage is not good on account of the situation or the soil, it should be improved by raising the beds slightly above the surrounding level and the center of each bed slightly above its edges. Ordinarily the beds can be raised sufficiently by shoveling out the paths from 2 to 4 inches deep. An ample edge should be allowed for the frames and for washing by rain. If the soil is very loose, it may be necessary to protect the edges of the beds by a board frame sunk in the ground.

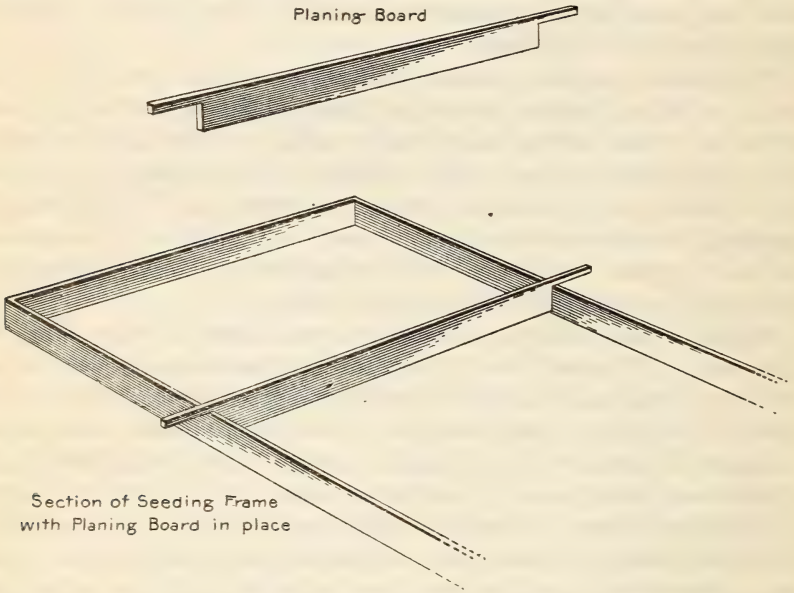

FIG. 2.—Seed-bed equipment.

The cost of preparing seed beds, including plowing, harrowing, spading, and raking, has been $0.0027 per square foot at the Boulder Nursery and $0.00416 at the Wind River Nursery.

SOWING OF SEED.

Seed sowing is considered by some as the most important single nursery operation. Sowing to secure the desired number of trees per square foot requires considerable knowledge, skill, and care. Hence, this is work that capable nurserymen handle themselves or supervise very closely.

The following points are of especial importance. All seed used in a nursery should be fresh and clean. Fresh seed germinates more vigorously and is less liable to rot than old seed, and it is not so likely to produce distorted, weak seedlings. Seed from local collecting is best because the seedlings produced are best adapted to the soil and moisture conditions and to the length

of the growing season at the nursery. When feasible the seed should be graded so as to eliminate the weak seed in the beginning and prevent the production of stock which is undesirable and will have to be discarded later on. Other things considered, the larger seeded forms of a species are to be preferred because they produce larger plants in the same length of time than the smaller seeded varieties.

In no case should seed be used whose germination per cent is less than the average for the best fresh seed of the species. Germination tests should be made, and the seed which is found unsuitable rejected. The use of seed whose quality is not known may result in very thin stands of seedlings and thus upset nursery and planting plans for a year or two. When regular germination tests have not been conducted, some knowledge of the quality of the seed may be obtained by cutting open 200 or more and noting the condition of the kernel or meat. If the kernel is plump and full and of a good cream or white color the seed is probably good. This test is not wholly a reliable or satisfactory one, however, since it usually gives higher percentages of good seed than are obtained when regular germination-test methods are employed.

Seed which will germinate at the rate indicated in the following table will generally prove satisfactory for nursery purposes. The figures were obtained through actual tests of 200 seeds of each species, sown in small flats filled with sand or soil and exposed to a greenhouse winter and spring temperature of from 60° to 80° F. The figure given under 100 days is not necessarily the final germination per cent of the species; but the percentage shown for each species listed is a very good one for a test covering that period of time.

Results of germination tests.

Species.	Germination per cent.			
	In 20 days.	In 30 days.	In 60 days.	In 100 days.
Abies concolor		2	7	10
Cupressus arizonica	25	33.5		
Larix occidentalis	25	30	40	
Libocedrus decurrens	44	54	61	64
Picea engelmanni	70–86			
Pinus contorta	60–70	70–85		
Pinus jeffreyi	24–30	40–45	70–75	
Pinus lambertiana	5–10	21–33	47–59	68–70
Pinus monticola	2–2.5	3– 4	12–14	42–45
Pinus ponderosa:				
Black Hills	60–65			
Colorado	76–90			
Arizona	80			
Montana	71			
Idaho	41–46.5	56–62.5	75.5–80	
California	30–36	36.5–42.5	69.5	86.5
Pseudotsuga taxifolia:				
Rocky Mountain form	70–74			
Idaho	21	43.5	61–69	
Coast form	3	10	46	63
Sequoia washingtoniana		30–38		
Thuja plicata	47			

METHODS OF SOWING.

Whether sowing shall be broadcast, in drills, or in flats will be governed largely by local conditions. Each method has advantages under certain conditions.

In drill-sown beds cultivation and weeding between the rows by means of small hand tools is possible, and root pruning can be practiced. Where cultivation is practiced there is less need of watering, and the soil is better aerated and is kept warmer and in better tilth. Even stands are more easily secured by an inexperienced man in drill sown than in broadcasted beds; seedlings can be more easily dug and with less damage to the roots, particularly in heavy soils, and in some cases winter damage from snow (as with Douglas fir at the Cottonwood Nursery) and heaving are less serious. Damping-off can be more readily controlled by cultivation when the beds are drill sown than when they are broadcasted, provided the conditions are such that cultivation is effective against the disease. Such cultivation, however, is seldom effective. On the other hand, the drill-sown seed in germinating may break the soil and leave an open ditch in line with the drills, thus exposing the seed which have not yet germinated. Where damping-off is prevalent this partly open ditch forms an ideal moist chamber for the development and spread of the fungus along the whole row. At the Priest River Experiment Station damping-off has been more serious in drill-sown western yellow-pine beds than in broadcasted. Drill sowing is not well adapted to the sowing of seed with a low germination per cent, because the drills must be made deep and the seed sown very thick in the row, with the result that a portion of them do not come in contact with the soil, and the bottom seed are covered so deeply that upon sprouting they are unable to push their way through the covering above them.

In broadcasted beds cultivation is not possible and weeding must be done by hand, but if the beds are fully stocked the plants will shade the ground completely, decreasing evaporation and killing out the weeds, so that there is less need of these operations. A greater number of good seedlings can be grown per square foot in broadcasted beds; if necessary an area can be resown without disturbing the original stand; and the plants are less crowded and in general reach better development than in drill-sown beds. Broadcasting permits the necessary heavy sowing and uniform covering of seed having a low germination per cent.

In general it seems that in heavy soils or at nurseries where the water supply is deficient, either of which makes cultivation desirable, or where root pruning is to be practiced drill sowing is preferable. Where cultivation appears unnecessary and the water supply is suffi-

cient, or where it is desirable to effect an economy in space, as under high shade frames, broadcasting is preferable. In Forest Service nurseries broadcasting is coming more and more into favor.

Sowing in drills.—In the drill method the seed are distributed in drills from 3 to 6 inches apart and from one-fourth to one-half inch deep by means of a hand seed drill, or a seeding board, or by hand. If a seed drill is used, it has to be regulated by trial to sow the proper number of seed per linear foot. After the drill is regulated the hopper is filled with seed and the drill is pushed ahead in a straight line. At the Cottonwood and Pilgrim Creek Nurseries drills have proved twice as rapid as broadcasting. However, there are some drawbacks—resinous seed stick and do not feed well; the seed must be very clean; it is difficult to regulate the drills so that they will distribute the seed evenly, especially small seed; and the drills are not so well suited for sowing across the beds as lengthwise.

For drill sowing across the beds a marker, hinged seeding board, and a seed trough (see fig. 3) have proved highly efficient. The marker consists of a plank 4 feet long, 15 inches wide, and 1½ inches thick, with two handles projecting beyond each end, and with triangular strips of wood from one-half inch to 1 inch thick on a side and 4 feet long, nailed longitudinally and parallel, from 3 to 6 inches apart, on its under side. By pressing these triangular strips or cleats into the soft earth of the prepared seed bed perfect V-shaped depressions can be made of the depth desired. Two men can mark from 100 to 200, 4 by 12 foot beds per day with this board, depending upon the depth desired and the condition of the soil.

The seeding board consists of two strips of board 4½ feet long, 3 inches wide, and three-fourths inch in thickness (narrow bevel siding is sometimes used), joined edge to edge by a small hinge at each end. The adjoining edges of the boards for a distance of 4 feet (the width of the seed beds) are beveled on the top side between the hinges, one edge much more than the other, so that a shoulder is formed on which seed uniformly distributed will remain when the board is dipped into the trough partly filled with seed, then tipped each way so that all superfluous ones will fall back into the trough. By varying the depth of the groove and the width of the shoulder on the adjoining side the board can be made to sow any quantity desired. One of the outer edges of the board is beveled far back on the under side so as to offer no obstruction when the seed is dipped. Two men operate it, one at each side of the bed. The board is dipped with a swinging motion into the trough and then lowered and held close over the drill to be seeded; the hinges are bent upward, and the seeds fall into the drill.

The seeding trough is 8 inches deep, rounded slightly on the bottom and up one side, from 10 to 14 inches wide, and 5 feet long. It

is mounted on legs, raising it from 16 to 24 inches above the ground. The trough is set to straddle a seed bed in which drills have been

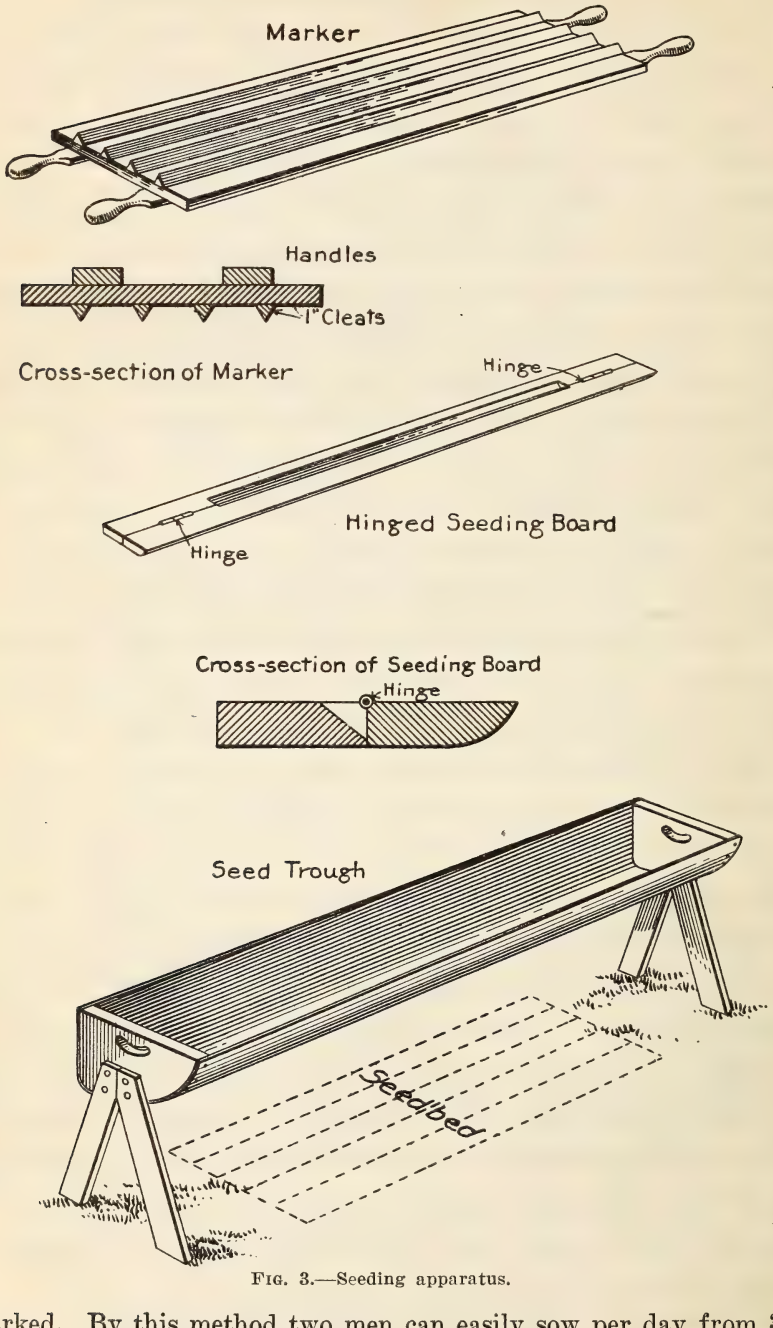

FIG. 3.—Seeding apparatus.

marked. By this method two men can easily sow per day from 30 to 40, 4 by 12 foot beds, of 48 drills each, and as many as 60 have been

sown. The seed is covered by another man. Working too rapidly should not be allowed, since speed induces carelessness with the average workman. The nurseryman himself should, if possible, be one of the crew to manipulate the board, or he should select very reliable men for the operation.

Drills are also made with a concrete roller fitted with parallel, evenly spaced cleats extending its entire length (Pl. III, fig. 2) and with a large, heavy wooden rake whose teeth are spaced at the right interval; and seed sowing is conducted by hand, with shotgun shell, or with a tin can with a hole punched in the bottom. None of these methods, however, are so rapid nor any more efficient than the first described.

Broadcast sowing.—In broadcasting, seed is scattered by hand over the prepared beds. The total amount is not entirely distributed the first time; a portion is reserved, so that the sower may again cover the area and scatter it where there is a sparse distribution. Proficiency in broadcast sowing is obtained only after considerable experience, and even stands of seedlings are not so readily secured by an inexperienced man as in drill sowing. When the sower is experienced this method is rapid, one man when not covering the seed being able to sow an area of from 4,000 to 9,000 square feet in a day. After sowing the seed should be pressed into the soil by means of a wide, flat board or by a light roller. The board or roller should be dry, or the seed will stick to it.

Sowing in flats and pots.—For southern California, where the climatic conditions are especially trying on young planted trees, some transplant stock is produced in individual paper pots. The seed are sown in flats, and the seedlings transplanted into the pots, which are later set out in the field.

Several small holes are bored through the bottom of the flats, one-half inch of small gravel is put in to allow for drainage, and then 4 or 5 inches of good loamy soil. This is packed in, the surface is smoothed, and the seed is sown and covered.

Sowing in flats has three advantages—very good drainage can be provided for the seedlings, the depth of the covering of the seed can be well regulated, and transplating is easier. On the other hand, it is more expensive than raising stock in seed beds, because of the added cost of flats, mixing of the soil, and more intensive care. It has also been found with conifers that the stock produced has a very inferior unbranched root system.

The sowing of conifers directly in the pots has also been tried. This scheme appears to have little to commend it. It is expensive, the seedlings in a large number of pots are likely to die, necessitating their resowing, and a thrifty class of stock is not produced in most instances.

SEASON FOR SOWING.

The season for sowing is largely determined by the species raised, by local climatic conditions, and by experience in nursery practice. If the seed is of a species which germinates slowly, such as western white pine, sugar pine, the Pacific coast form of Douglas fir, or incense cedar, heavier and better developed stands of seedlings are usually secured by sowing in the fall than in the spring. Some seed, such as deodar cedar and the true firs rapidly lose their vitality. For these fall sowing immediately after their collection is also preferable. In most cases species whose seed germinate rapidly can very well be sown in the spring, so as not to be exposed over winter to damage from rodents or subject to the danger of extremely early germination and subsequent killing by late frosts. However, spring sowing, even of such species, is not always thought desirable. Damping-off is less severe, for instance, in fall-sown than in spring-sown beds of jack pine at the Bessey Nursery.

At the Pocatello Nursery it is thought best to sow in the late spring, because the weather is so cool during the spring that no advantage would be gained by fall or early spring sowing. In Arizona and New Mexico, where the spring of the year is very dry, some of the sowing is deferred until the near approach of the rainy season, which occurs in July and August. Seed sown in these States in the spring requires frequent watering after germination; those sown in the summer do not need artificial watering. Damping-off, however, is less severe there in spring-sown than in summer-sown beds.

Fall-sown seed have a long period in which to absorb moisture, and germinate rapidly upon the advent of warm spring weather. Watering of the seed beds to induce germination is usually unnecessary. Moreover, the stock from fall-sown seed is more likely to be fully hardened and able to withstand early fall frosts than that from spring sowing. Stock larger by from one-half inch to 2 inches can be produced in one year by fall than by spring sowing. The increased growth may mean the shortening by a year of the length of time necessary for growing stock to a size suitable for field planting, thus effecting an economy of space in the nursery and reducing the cost of the plants (Pls. IV, V, XV).

AMOUNT OF SEED TO SOW.

The optimum number of seedlings per square foot in seed beds varies according to the species, the region (because of the longer growing season and greater development of the stock in some regions than in others), the manner of sowing (broadcasting or in

F–85923

FIG. 1.—CLEARING LAND FOR A NURSERY.

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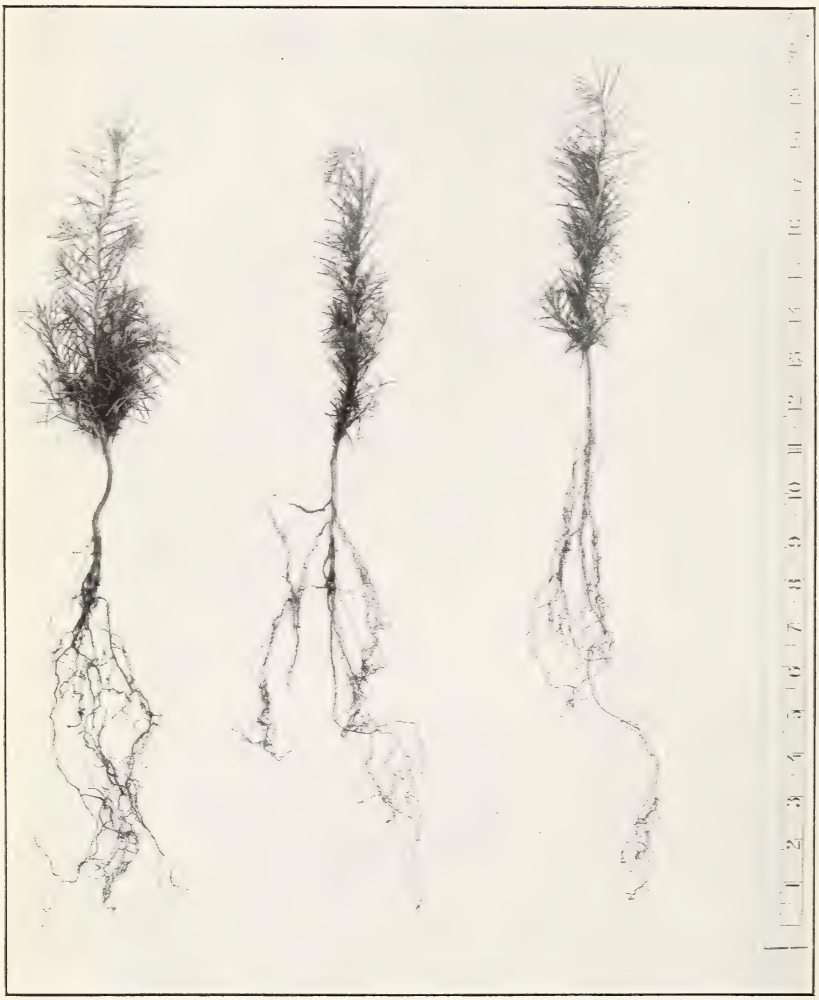
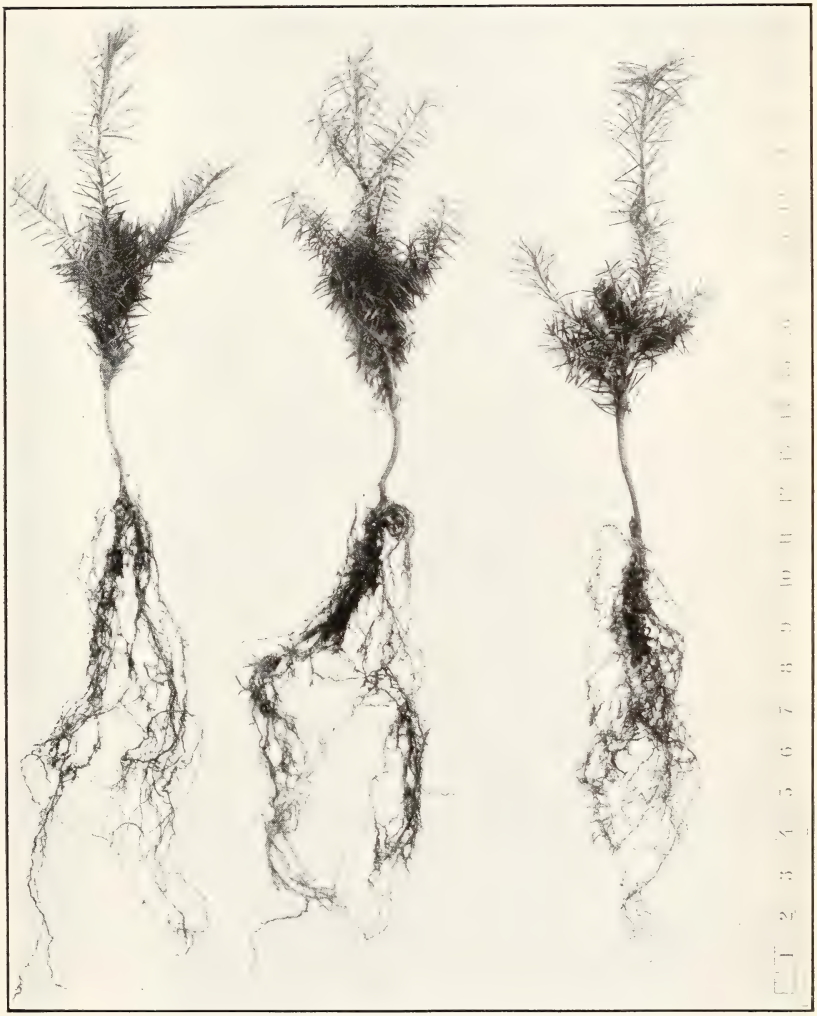
FIG. 2.—CONCRETE ROLLER FITTED WITH WOODEN CLEATS FOR MAKING DRILLS IN SEED BEDS.



F-3796A

1-1 DOUGLAS FIR FROM SPRING-SOWN SEED, WIND RIVER NURSERY, COLUMBIA NATIONAL FOREST.

Compare with that from fall-sown seed. Note greater development of latter (Plate V).



F–3794A

1-1 DOUGLAS FIR FROM FALL-SOWN SEED, WIND RIVER NURSERY, COLUMBIA NATIONAL FOREST.

Compare with that from spring-sown seed (Plate IV).

COMPARISON OF SEEDLINGS GROWN UNDER DIFFERENT DEGREES OF DENSITY.

A, Grown 4,000 per bed; *B*, grown 6,000 per bed; *C*, grown 8,000 per bed; *D*, grown 10,000 per bed; *E*, grown 12,000 per bed.

drills), and length of time that the stock is to be left in the seed beds. The optimum density must be determined through experience. Too heavy stands make the stock spindly, and necessitate more seed, more work, and more grading than stands of the proper density (Pl. VI). Very light stands produce seedlings of good quality; but, as the area is not fully utilized, the cost of the stock is greater than it need be. In Table 3 the densities striven for by the nurseries in the region indicated, as well as the season of sowing, are shown.

The density of stocking can be regulated by the amount of seed sown. The density desired and the germination percentage of the seed being known, the number of seed to sow per square or per linear foot may be determined by use of the following formula:

$$\frac{\text{Number of seedlings desired per square foot or per linear foot} + \text{from 10 to 20 per cent.}}{\text{Germination percentage of seed.}}$$

If germination is less complete or there is more loss in the seed beds when seed is sown at one season than at another, this will have to be given due consideration. The additional 10 to 20 per cent is to allow for poorer germination in seed beds than that secured in the tests and for losses after germination. To determine the weight of seed to be be sown per seed bed the foregoing formula would have to be multiplied by the number of square or of linear feet per bed and divided by the number of seed per pound of sample.

TABLE 3.—*Seasons sown, and most desirable density of seedlings.*

Locality and species.	Season sown.	Most desirable density of seedlings.							
		Per linear foot of drill in drill sowing.				Per square foot in broadcast sowing.			
		1 year in beds,[1] for transplanting.	2 years in beds.		3 years in beds,[2] for field planting.	1 year in beds,[1] for transplanting.	2 years in beds.		3 years in beds,[2] for field planting.
			For transplanting.	For field planting.			For transplanting.	For field planting.	
West central Montana, altitude 3,150 feet:									
Larix occidentalis	April					200		65	
Picea engelmanni	do						250		95
Pinus monticola	October						250	155	
Pinus ponderosa	April					135		65	
South central Montana, altitude 5,000 feet:									
Picea engelmanni	May						240		
Pinus ponderosa	do					165		85	
Pinus sylvestris	do					165	120		
Pseudotsuga taxifolia	do						200		
Nebraska, sandhill Region, altitude 2,700 feet:									
Pinus austriaca	October-November					155	125		
Pinus divaricata	do					145	125		
Pinus ponderosa	do					165	125		
Pinus resinosa	May					180	125		
Pinus sylvestris	October-November					165	125		
Colorado, east slope of Rocky Mountains, altitude 7,200 feet:									
Picea engelmanni	do	35–50	25–35						
Pinus austriaca	do	25–50	25–35						
Pinus ponderosa	do	25–50	25–35						
Pseudotsuga taxifolia	do	25–50	25–35						
New Mexico, southern portion, altitude 6,470 feet:									
Cupressus arizonica	April-May		25				85		
Pinus jeffreyi	do	25				85			
Pinus ponderosa	do		25				85		
Utah, central portion, altitude 7,400 feet:									
Pinus ponderosa	September-October	100	100	75	40	150	150	100	60
Pseudotsuga taxifolia	May	200	250	135	50	250	250	200	75
Southeastern Idaho, altitude 5,200 feet:									
Pinus ponderosa	do					150		50–75	
Pseudotsuga taxifolia	do						200	175	125

Washington, Cascade Region, altitude 1,200 feet:									
Abies nobilis	November–December					200			
Chamæcyparis lawsoniana	April-May						95		
Larix occidentalis	do					120	95		
Pinus monticola	November-December					200	110	60	
Pinus ponderosa	do					160			
Pseudotsuga taxifolia	do					200			
Sequoia washingtoniana	April-May							40	
Southern Oregon, altitude 1,700 feet:									
Pinus lambertiana	October					125			
Pinus ponderosa	April-May					125			
Pseudotsuga taxifolia	do					125			
Northern California, altitude 4,000 feet:									
Abies concolor			60						
Libocedrus decurrens	October	60–80							
Pinus jeffreyi	May	65							
Pinus lambertiana	October		40						
Pinus ponderosa	May	80–110	40						
Sequoia washingtoniana	do					300			
Southern California, altitude 6,000 feet:									
Cedrus deodora	April		30						
Libocedrus decurrens	do		30						
Pinus jeffreyi	do		30						
Pinus ponderosa	do		30						

[1] No column for field planting because 1-year old seedlings are not set in the field.

[2] No column for transplanting because seedlings are transplanted before 3 years.

COVERING THE SEED.

In some cases the seed are covered by the drill itself. In others the covering must be a separate operation. It is ordinarily accomplished by sifting sand or soil over the beds through a screen of about one-fourth-inch mesh. One man can easily cover from forty to fifty 4 by 12 foot beds per day of 8 hours. Skill is required to cover the seed to a uniform depth so as to insure equable conditions and relatively even germination. There is a tendency to distribute the soil too deep over the center of the beds and too shallow along the edges. One method of covering requires a frame and planing board similar to those shown in figure 2. If broadcast sowing is practiced, the frame need not be removed from the time the bed is first leveled until covering has been completed. The soil used in covering is sifted over the seed bed, and a planing board, narrower by the depth to which it is desired to cover the seed than the one used in sowing, is then drawn along the frame. By this means the seed is covered at a very even depth. Some other methods of covering are followed. Soil is shaken off the blade of a shovel over the seed or scattered by hand. In drill beds sown by hand the seed is sometimes covered with the back of a rake or, as in one of the most successful Forest Service nurseries, by drawing the finger through the soil between the rows, thus closing the open drills.

The depth of covering most suitable for any one species varies according to differences in soil and nursery practice. Even under very constant conditions some latitude may be exercised without danger of seriously affecting the germination of the seed or their subsequent pushing through the covering. If heavy clay soil is used as a cover, the maximum depth permissible can not be so great as if a lighter sandy soil is used because the seedlings experience greater difficulty in breaking through. By reason of their greater size and strength seedlings from large seed can more readily push through a heavy covering than seedlings from small seed. Therefore, the former can safely be covered more deeply than the latter.

Less work is necessary to put on a light cover than a heavy one, and the seedlings appear sooner and more evenly in the beds. It is true that with a shallow covering there is greater probability of the soil becoming dry to the depth of the seeds, resulting in damage to them; but this possibility can not be avoided by any depth of covering consistent with good nursery practice. Danger of this nature must be guarded against by frequent watering or by protecting the seed beds. When moisture conditions in the seed beds can be controlled, Forest Service experience indicates strongly that shallow coverings are preferable, from one-eighth inch with smaller classes of seed, such as spruce, the Thujas, larch, lodgepole pine, and

red pine, to three-eighth inch with larger seed, such as white pine, Douglas fir, western yellow pine, and Jeffrey pine. Germination is better and more uniform, and at the Bessey and Savenac nurseries damping-off is less severe in shallow than in deeply covered beds.

A loose, friable soil, such as sand or a mixture of sand and loam, makes the best cover. A cover of sand gives quicker and more uniform germination than any other; it can be put through a screen more easily; it retards evaporation excellently, more effectually prevents caking of the surface and the lifting of cakes bodily by the germinating seed; it decreases the danger of damping-off, and it gradually improves the texture of a heavier underlying soil. Furthermore, moss is less likely to form on a sandy than on a loamy surface.

COVERING OF THE SEED BEDS.

After sowing and covering the seed there is, at some nurseries, an advantage in covering the seed beds. Protection of the seed against rodents, particularly mice and chipmunks, and of the seedlings (when they first appear above the surface of the soil with the seed coat attached) against birds is very often necessary. A common and effective means of protection is a screened frame cover of the same size as the seed beds, ordinarily 4 by 12 feet, the bottom sill sunk into the soil around the seed bed, and the top high enough above the bed so as not to interfere with the development of the seedlings. The top is removable to permit weeding. Such a frame, called a "Pettis frame," is described in Forest Service Bulletin 76, and the drawings are reproduced here (fig. 4).

A modified type of this frame is used at the Wind River Nursery. The corner and side posts project an inch above the top plate in order to hold the cover in place on the frame. Further, the sides and ends are constructed separately and the frames afterwards set up. This method of construction results in two posts at each corner, one of which fits in front of the other. The frame is set up by bolting the two corner posts together or simply by inserting a large 20d. nail in the hole bored for the bolt. The principal merit of this is that the frames can be quickly taken apart and when stored require much less space.

Before construction the framework material should be painted to preserve the frames and improve their appearance. Experiments at the Wind River Nursery indicate that a light grade of creosote applied to the lower sill of the seed-bed frame will not harm Douglas fir seedlings if not more than two coats are given. Carbolineum of the grade used proved unsatisfactory. Both of these preservatives vary so much in grades that in general it is unsafe to use them unless they have been proved satisfactory by experiment.

Wire mesh for covering the frames can be purchased in rolls 150 feet in length and in widths of 4 feet for the top screen and 1 foot for the sides and ends of the frames. The 1-foot strip is cut in 6-inch widths. Experience at Forest Service nurseries has demonstrated that screen as fine as three meshes to the inch is necessary to keep mice out of the seed beds.

The cost of these frames complete, including a shade frame of lath, is from $3 to $7 each, depending upon the lumber used and the skill and wages of the men who construct them. Money can be saved by purchasing material which is surfaced on four sides, since it can

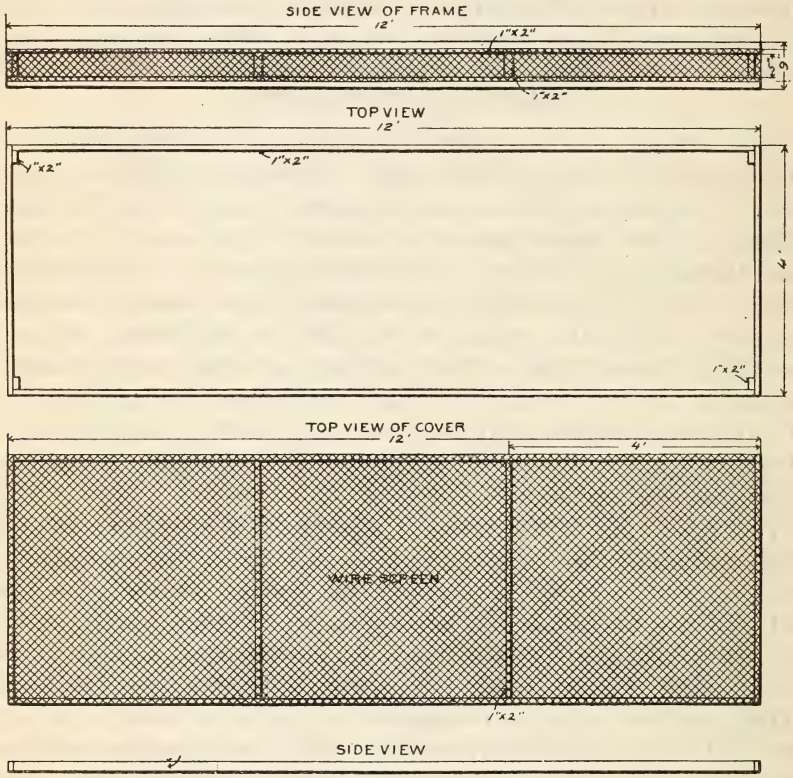


FIG. 4.—Pettis seed-bed frame.

be painted much more rapidly and requires less paint. Such frames ordinarily last only from 3 to 5 years or will need repairing by the end of that time. The bottom sill in particular is very liable to rot.

At the old Garden City Nursery protective frames were used whose sides and ends were of 1 by 8 inch boards, the top only being covered with wire screen. These were more satisfactory at this nursery because they afforded a better protection against wind, and were considerably cheaper than the wire frames.

Covering of the seed beds during the germination period is resorted to for other reasons than protection against rodents or birds. Chief among these is keeping the beds as uniformly moist as possible, which undoubtedly promotes the highest germination of the seed. Covering also eliminates the need of such frequent waterings as are necessary in uncovered beds. For the purpose of keeping the beds uniformly moist, the sides and ends of the wire frame just discussed are covered with building, tar, or wrapping paper, or burlap, and a lath shade frame is set on top of it. Burlap is better than paper because it is easier to handle, does not tear, and can be used for two successive years. The lath frame is constructed as shown in figure 5. A complete shade or covering is obtained by laying a loose lath in each interspace between those which are nailed to the frame. Full or partial shade, without the side covering of burlap, is often given the beds by means of this lath frame, some other form of a low-shade frame, or high-shade frames with a slatting cover.

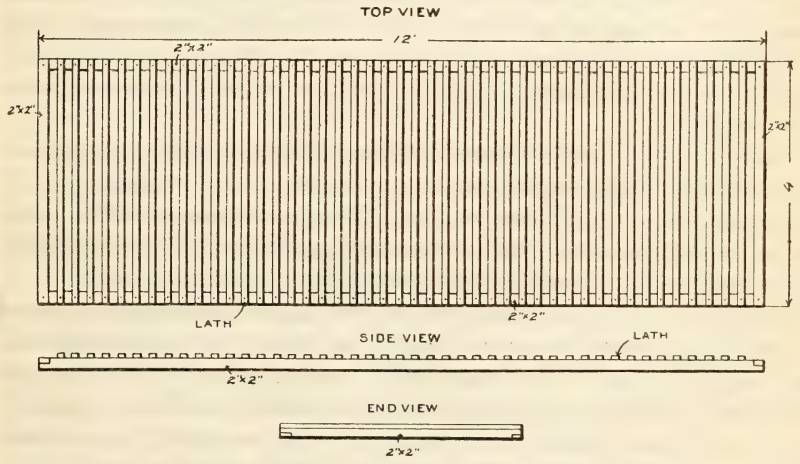


FIG. 5.—Pettis seed-bed frame.

Recent experience has developed the fact that such shade coverings are neither necessary nor desirable in all nurseries where they have been used. This is especially true in the cooler and moister regions and with seed which germinates slowly. Heat as well as moisture is essential for germination of seed; and in moist seed beds tightly screened from the sun's rays, the temperature of the soil may be kept so low as to delay germination considerably. This happened with Douglas fir at the Wind River Nursery. Seed in seed beds without side or overhead cover, or with a cover of one thickness of burlap only, germinated twice as fast in the first month as those under the regular Pettis frames. At the Cottonwood, Pilgrim Creek, and

Monument Nurseries no shade is given until after germination is in progress.

Other covers are often given seed beds to conserve moisture. Burlap is quite commonly stretched flat across the beds, and straw, moss, or leaf mold to a depth of about an inch is sometimes sprinkled over them. Any of these latter coverings must be removed soon after germination commences. For several reasons burlap is the best cover; it can be put on and removed easily; it does not bring weed seed to the bed; it effectually prevents the wind from shifting the surface soil of the beds; it does not mat down and heat; it allows the sun's rays to filter through to warm the soil better than the other covers; and to some extent it protects the beds from birds. Straw, moss, or leaf-mold coverings can not be put on so rapidly nor distributed evenly; they keep the ground cold, thus delaying germination; they often bring weed seed to the beds; they are likely to be blown off by wind; and after germination commences their removal can be accomplished only slowly, not cleanly, and scarcely without damage to numerous seedlings, which when first appearing in the beds are quite brittle and easily broken off. Moreover, where this type of cover has been used, damping-off has, at some nurseries, been more serious.

In the very dry and hot Southwestern States the efficiency of a burlap cover for retarding evaporation is increased by covering it with about one-half inch of fine, dry soil. This procedure would be satisfactory only with seed which germinate rapidly and will not, accordingly, require additional watering after the cover is put on.

In localities where the temperature during the germinating period is very high, where it is very windy, or where the seed germinates very rapidly, the Pettis frame with burlap around the sides and full shade on top is a desirable cover; in cooler localities, especially with slowly germinating seed, no cover at all or simply one of burlap is preferable, provided in each case the sowing operations are conducted in the spring. In seed beds sown late enough in the fall so that there is no possibility of fall germination, no cover at all for the purpose of preventing evaporation is necessary. Protection against rodents, birds, and the removal of the soil by wind is still necessary, and for this the same methods should be followed as in spring sowing.

WATERING OF SEED BEDS.

Immediately after sowing and covering the seed, the beds should be given a thorough watering. This will usually expose seed which have not been covered deeply enough, settle the soil a little more thoroughly, establish capillarity, and furnish the moisture necessary to initiate germination. Between sowing and actual sprout-

ing, the seed is in its most delicate condition and most subject to loss of vitality from drying out. When germination activities are once started they should not be checked by lack of water. Moreover, insufficient water may cause seed to lie over until the following year before germinating. An uneven-aged stand of seedlings will result. This condition is a nuisance in nursery practice because it necessitates close grading of the stock when it is dug. The moisture condition most conducive to germination is that where the soil is simply fresh or only slightly moist but not wet. An extremely moist or wet soil is not conducive to rapid germination, and may cause the seed to rot. It is not possible to preserve absolutely uniform moisture conditions in the seed beds continuously, but the nearer such conditions can be approached the better will be the germination.

Beds should be watered only often enough to prevent their drying out. The periods of watering will vary so extremely with the character of the season, the soil, and the nature of the covering given the beds that no definite rules can be framed. Inspection of the beds is the only safe guide. It is better to water often and moderately than a few times and heavily. This may mean from once a week or even 10 days under rather favorable conditions or where mulching is practiced to twice a day during very hot, dry weather. When necessary to water daily, it is better to water in the evening than in the morning. When watered in the evening a bed remains moist until the next morning at least, and perhaps until noon. Thus it is sufficiently moist for 18 or 20 hours. When watered in the morning on a clear, warm day, a bed is likely to become dry by sundown, because the greatest evaporation occurs during the middle of the day. Watering later than 3 p. m., however, is considered poor practice at the Pilgrim Creek Nursery, because the seed beds then remain cold over night. The time of watering must thus be related to the daily range in temperature where wide extremes occur.

When fall sowing is practiced or when a rainy season follows sowing, the necessity of watering during the germination period will ordinarily be obviated. In Arizona and New Mexico beds thoroughly soaked before early spring sowing of seed which sprout quickly, and then covered with burlap and about one-half inch of soil, do not need watering during the spring.

A number of methods may be employed: By hand with the hose, by means of garden sprinklers, or by irrigation. The first is slower than the others, but is unquestionably the best from the standpoint of efficiency under all conditions. The water can be distributed evenly in the form of a fine spray to all parts of the beds. Lawn sprinklers are more rapid because as many of them as the water pressure will permit can be kept going at one time. They do not

distribute the water so evenly, however, and unless closely attended and frequently shifted, they fail to distribute sufficient water to some portions of the beds, especially the corners. This is particularly true in seed beds with low frames, because these intercept the spray. Nevertheless, when well conducted, this method is quite efficient.

The common lawn sprinkler with three or four whirling arms raised on an 8 to 16 inch standard has proved quite satisfactory. At the Wind River Nursery a wire edge formed on the wearing surface after a while and retarded the motion. Minute débris in the water clogs and stops the sprinklers, and they sometimes leak and wash the soil badly where they are placed. Their cost is from $1 to $1.25 each. Another style of sprinkler which has proved satisfactory is made in a single casting and resembles an inverted bowl or a cone with one or two $\frac{1}{4}$ or $\frac{3}{8}$ inch holes at the apex. The sprinklers throw out an inverted cone-shaped spray to a radius of 10 feet or more. They never clog and their cost is from 15 to 25 cents each. For convenience in dragging it around, each sprinkler can be mounted on a piece of plank about 10 inches square, with two sharp-edge runners on the lower side to prevent its working sideways when drawn over uneven ground in the paths between the beds.

The possibilities of irrigating in seed beds before germination have not been determined for all conditions. At the Pocatello Nursery subirrigation from ditches 3 feet apart was tried. It was found to be satisfactory with western yellow pine but not with Douglas fir. The beds could not be kept moist enough to induce good germination of the latter species. At present sprinkling is followed at all Forest Service nurseries when watering is necessary during the pregermination period, and it is thought that this is preferable to irrigation, whose general practicability is very doubtful.

At a number of nurseries cotton or canvas hose is considered superior to rubber. Second-grade cotton hose lasts two or three years, or about the same as rubber hose; it is much lighter and easier to handle than the latter; it does not damage the stock so badly if dragged across the beds and is cheaper. The $\frac{3}{4}$-inch size outlasts the 1-inch, because it is more pliable and kinks less easily. At the Pocatello Nursery a crack-proof rubber hose is used and gives very good satisfaction.

LENGTH OF TIME REQUIRED FOR FULL GERMINATION.

The length of time required for full germination can scarcely be given accurately, because it varies markedly with different soils, different methods of nursery practice, differences in the quality or source of the seed, and variations in the climatic factors. The approximate length of time after spring sowing necessary for practi-

cally complete germination is indicated in the following table for several of the Forest Service nurseries:

Nursery and species.	Germination complete.	Nursery and species.	Germination complete.
	Days.		*Days.*
Savenac:		Fort Bayard:	
Pinus ponderosa	25	Pinus ponderosa (summer sowing)	15
Larix occidentalis	40	Pinus jeffreyi	15
Trapper Creek: Pinus ponderosa	24	Cottonwood:	
Boulder:		Pinus ponderosa	30 to 35
Pinus ponderosa	30 to 35	Pinus contorta	30 to 35
Pinus austriaca	30 to 35	Pseudotsuga taxifolia	30 to 35
Pinus sylvestris	30 to 35	Picea engelmanni	20
Pseudotsuga taxifolia	40 to 50	Pocatello:	
Monument:		Pinus ponderosa	20 to 30
Pinus ponderosa	10 to 18	Pseudotsuga taxifolia	45 to 60
Pinus austriaca	10 to 15	Pilgrim Creek:	
Pseudotsuga taxifolia	10 to 15	Pinus ponderosa	34
Picea engelmanni	10	Pinus jeffreyi	80
Bessey:		Abies concolor	66
Pinus ponderosa	9 to 20	Libocedrus decurrens	64
Pinus divaricata	9 to 20	Pseudotsuga taxifolia	58
Pinus resinosa	14 to 25	Wind River: Pseudotsuga taxifolia	35 to 50
Pinus sylvestris	12 to 20		
Minnesota: Pinus resinosa	20		

METHODS USED TO HASTEN GERMINATION.

The seeds of a number of conifers germinate so slowly in the aggregate that some method is occasionally used to hasten this function. Western white pine seed is particularly slow, but as yet no successful method of hastening germination has been devised. The seed will not finish germinating in the seed beds for 2 or 3 years, which complicates the nursery operations considerably. A common method tried for various species is to soak the seed in water for a number of days until they swell and begin to sprout. Other methods are to mix the seed with well-rotted compost and soil until sprouting begins, to stratify them in slightly moist sand in a cool place over winter, or to scald bony coated seed in nearly boiling water and allow them to stand in the water for a couple of days.

The efficiency of the first two methods is doubtful. As soon as the seed begins to sprout it is necessary to sow the whole lot, and there is no certainty that the seed have sprouted because of the treatment or that the unsprouted ones have benefited. Even with slow-germinating seed like the western white pine, a small proportion of any lot when simply sown in the beds without previous treatment will germinate in a short time, and it is almost unquestionably these same seed which are the first to sprout under special treatment.

Stratifying in sand over winter in a cool place will undoubtedly hasten the germination of nearly all coniferous seed. The period is long enough so that that the seed have ample time to absorb the moisture necessary for their germination, and the temperature is low enough to prevent germination until the following spring. This method has been followed successfully even with *Juniperus pachy-*

phlæa seed, which, like other junipers, ordinarily lies over for a year if sown in the spring without being previously treated.

At the Fort Bayard Nursey fair germination is secured with the seed of *Juniperus monosperma* by removing the hull and then immersing the seed in boiling water for 5 seconds. At the old Garden City Nursery good germination was secured with *Juniperus virginiana* by removing the hulls, soaking the seed in warm water for from 2 to 4 hours, and sowing in the fall.

CARE OF SEEDLINGS THE FIRST YEAR.

The care of the stock from the time of germination until the plants are ready for field planting has much to do with the mortality, the development of tops and roots, and the final success of the field planting. Operations should be directed toward developing the type of plant most suitable for field planting and toward growing the greatest possible number of these in the allotted space. Wide experience in the United States and Europe has fully demonstrated that plants with stocky tops, thick stems and compact-growing shoots, and compact root systems composed of many lateral but not extremely long, fibrous roots, are more likely to succeed in field planting, particularly under inhospitable conditions, than plants with greatly developed tops and long root systems with few laterals. Shading and watering are two of the most important means of producing such plants and of keeping down the percentage of loss in the nursery.

SHADING.

The effect of shading is to lower the temperature and increase the relative humidity of the air below the shade frames, diminish evaporation from the soil and plants, increase the height growth of the seedlings, and lessen the amount of watering necessary. It also prolongs the growing period of the plants into the autumn longer than is always desirable, subjecting them to danger from early frosts and sometimes causing the seedlings to reach a size greater than that considered best for transplanting.

The necessity of shading is greatest during the first season of the plants' growth. They are then small and tender and may be damaged by continuous intense sunlight. Their density results in considerable competition for moisture, and the roots are not well enough developed at the beginning of the season to secure moisture at a considerable depth.

The necessity and amount of shading varies with the species, soil, and region. Some species, such as Norway and Engelmann spruce, appear to need considerable shade at all nurseries; others, such as Douglas fir, will thrive without shade in some regions but demand

F–92507

FIG. 1.—ONE TYPE OF LOW SEED BED PROTECTIVE FRAME IN PLACE, WITH AND WITHOUT COVERS.

F–10905A

FIG. 2.—TYPE OF LOW SHADE FRAME IN USE AT THE BESSEY NURSERY.

Some of seed beds covered with burlap.

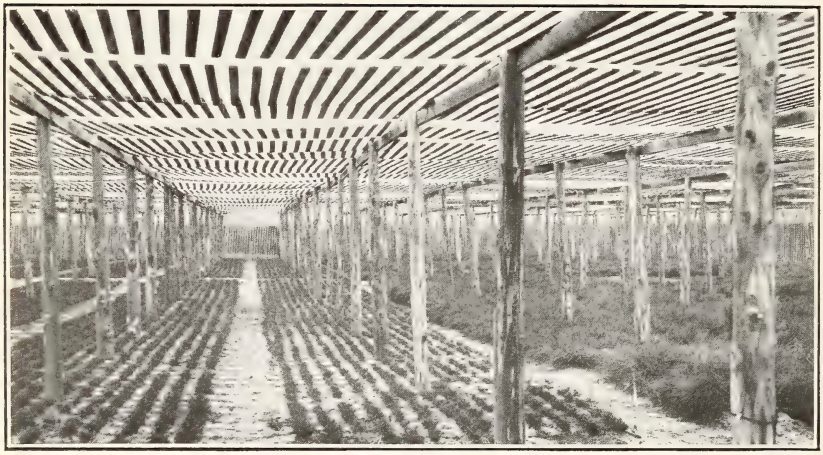


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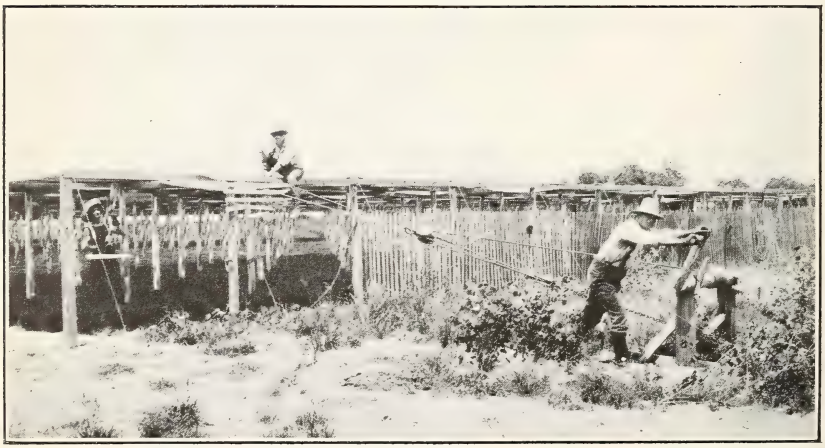
FIG. 1.—HIGH SHADE FRAMES.



F–68852

FIG. 2.—ONE METHOD OF TIGHTENING UP SLATTING COVER ON TOP OF HIGH SHADE FRAMES.

it in others. Without shade, seedlings may thrive on the richer, more retentive soil of a nursery but make poor growth on less fertile soil. Because the period of their initial growth falls in the early spring, when the weather is not extremely hot, seedlings from fall-sown seed are not so likely to need shade as those from spring-sown seed.

At the Savenac Nursery, in western Montana, western yellow pine is grown without shade, but the eastern and western white pines, Engelmann spruce, western red cedar, and western larch need partial shade during hot weather.

At the Boulder Nursery, in southwestern Montana, western yellow pine is grown without shade, but Douglas fir and Engelmann spruce require it during the first year.

At the Bessey Nursery, in the Nebraska sandhill region, all coniferous species are shaded during the first year.

At the Monument Nursery, in central Colorado, one and two year old Engelmann spruce and Douglas fir are given shade.

At the Fort Bayard Nursery, in southern New Mexico, shade is unnecessary with western yellow and Jeffrey pines, and *Juniperus monosperma*. Shade is given *Juniperus scopulorum* and *Cupressus arizonica*, but it is not known to be needed.

At the Cottonwood Nursery, in north-central Utah, western yellow, Scotch, and Austrian pines need no shade; Douglas fir can sometimes be grown without it, but usually Douglas fir, the larches, and Engelmann spruce require it for their best development.

At the Pocatello Nursery, in southeastern Idaho, western yellow pine does not need shade, but Douglas fir does.

At the Wind River Nursery, in southern Washington, all one-year seedlings from spring-sown seed are shaded, but Douglas fir and western yellow pine from fall-sown seed thrive satisfactorily without it.

At the Pilgrim Creek Nursery, in northern California, western yellow pine is grown without shade. All other species, including Jeffrey and sugar pines, incense cedar, and white fir are shaded, but it is not known that all need it.

At the Converse Flats Nursery, in southern California, all species grown, including western yellow and Jeffrey pines and incense and deodar cedars, are shaded during their first year.

Shade frames.—There are two general types of shade frames used in nursery operations, the high and the low. The most common form of the latter is the lath frame previously described. When in place this frame rests about a foot above the level of the beds and can easily be handled by one man.

A form of low frame used at the Bessey Nursery is about 22 inches high (Pl. VII). Stakes made of 2 by 4's are driven in the paths

at 8-foot intervals on both sides of the beds and 2 by 4's are laid on and nailed to these uprights. This makes a line of stringers along each side of the bed extending its entire length. Strips of slat or lath fencing are rolled out over these stringers to furnish shade. The slatting can be handled by one man and can be quickly rolled up if cloudy weather makes this desirable; the stakes and stringers can easily be moved when it is necessary to plow or grade; and the slatting is high enough above the ground so that weeding can be conducted without removing it. One man can construct about 400 linear feet of this type of frame per day.

The posts and framework of the high frames occupy the ground constantly (Pl. VIII). Durable first-class posts about 10 feet long are set in the ground in check rows from 10 to 12 feet apart, so that their tops are about 7 feet above the ground. Two sets of girders of rather heavy material (2 by 6's are preferable to 2 by 4's, as the latter are likely to buckle) at right angles to each other connect the tops of the posts. Over this framework rolls of slatting can be drawn. The framework must be substantially constructed because it is subject to considerable strain when the slatting is drawn across it and because the necessity often arises of a man working on top of it. The rolls of slatting are usually long enough to stretch entirely across the frame and down to the ground on each side so as to afford side shade and also to act as a windbreak. They remain in place from spring until autumn, thus subjecting the plants to half shade during the whole of the season. At the Pilgrim Creek Nursery 4 by 6 feet frameworks of slatting are used instead of the roll slatting. These are easier to handle, but are more easily broken.

The high frames have some advantages over the low ones. They do not interfere with weeding, cultivation, or watering, so that an inspection of these operations can more easily be made. The working conditions beneath them are more pleasant during extremely hot weather than in the open. The light is more diffused than under low frames, which is desirable in especially hot regions or when the species grown are susceptible to injury from the sun's rays. Under them the paths are kept moist as well as the beds; there is less danger of the stock being harmed by unseasonable frosts; the soil seems less liable to bake and crust than under low frames; and since the slatting remains on during the entire growing season, less watering is needed than with low frames, which are often removed. Their cost of construction of $2\frac{1}{2}$ to $3\frac{1}{2}$ cents per square foot is much less than that of the low wire protection and shade frames, and their life is considerably longer.

Objections to the high frames are numerous. They do not give adequate protection against birds and rodents. Two or more men

are required to put the slatting on or take it off, and it takes from 7 to 10 days per acre (two men from 3½ to 5 days) to complete the operation. The slatting is inconvenient to remove so that small areas under it can not be shaded or uncovered according to the requirements of the different species. The posts do not readily permit of plowing and harrowing in preparing the ground, so that these operations are more expensive; and they also interfere in the laying out, sowing, and covering of the beds. Rain collecting on and dripping from low points on these frames washes out either seed or seedlings. The frames do not hold a mulch in place well. At Forest Service nurseries high frames are being used less and less.

In case of emergencies, brush frames can be used. The principle of these is to use brush to furnish the shade. In high frames additional light stringers may be necessary to support the brush because of its irregular size. For this purpose wire serves very well. Brush frames have some advantages; there is no material quite equal to brush as a light filter; it is cheapest when the nursery is located in a remote region with poor communication by wagon road to a source of lumber supply; it is more easily removed after a heavy snow than sections of lath roofing; and it can quickly be put up if a special need for shade should suddenly develop at a nursery. On the other hand, it has disadvantages; the leaves and small twigs are continually falling on the plants and must be removed to prevent smothering; the brush is very inflammable, and it is not easy to spread, especially on high frames. Brush when used should be of as heavy foliaged species as are available.

REMOVAL OF SHADE FRAMES.

The most critical time in growing plants is the 6 weeks following germination, for during this period they are most subject to damping-off. Shading and watering have an important bearing upon the control of this disease. If germination occurs during cool weather or during hot weather when the surface soil is extremely wet, the shade frames should be removed. As soon as the soil surface becomes dry in hot weather, full sunlight is dangerous. It may give rise to "white-spot" injury, regularly confused with damping-off, but caused by overheating the surface soil. The object of the removal of shade frames is to dry the surface soil and lower the air humidity over the beds. This condition is least favorable to the development and spread of the damping-off fungi.

When practicable, the shades should be removed during periods of rainy weather. The water reaches the soil better and the plants become somewhat accustomed to a greater degree of light. It is generally held that during late summer and early fall the shades

should be removed gradually; that is, for an increasing period each day, beginning with exposure for a time during the cooler portion of the morning and afternoon and increasing this until, after 10 days or 2 weeks, the shade frames are left off entirely. In Forest Service practice this has not been found wholly necessary. The shades are often left on until the plants become fully hardened. It is certain, however, that the gradual removal of the shade does hasten this ripening process and puts the plants in better condition to withstand frosts. Until the terminal buds are fully formed, the shade frames should be replaced whenever the nights threaten to be frosty.

WATERING.

In conjunction with removing the shade frames to prevent damping-off, the watering must also be regulated to induce dryness of the beds. During this danger period no more artificial watering should be practiced than is absolutely necessary to keep the plants in good condition. When it is necessary to water daily, the application should be as light as conditions will allow and should be carried out during the morning hours. When watered in the morning, the beds dry out considerably during the day and do not pass the night in a moist condition very suitable to the development of this disease.

When there is no further serious danger from this source, the practice followed in watering should change. Soil moisture has more influence upon root development and perhaps upon the mortality per cent of seedlings after the damping-off period has passed than any other one factor. In seed beds the plants are crowded, and, unless the moisture in the soil is ample, some of the seedlings are killed out in the competition for water. If there is not enough water near the surface, the roots of those which live go deep in their search for it, and the little-branched, undesirable type of root systems is developed.

As water is one of the easiest factors to control, any advantage to be gained from its judicious use should be followed up. The aim in watering should be to attain a much-branched root system, with an abundance of fine feeding laterals within the first 10 inches of depth. To secure such roots the soil should be kept fresh near the surface. The kind of soil has an important bearing on the amount of water necessary. In light, sandy, well-drained soils an abundance of water may be used and will increase the root development, but in heavy clay soil excessive moisture seems to decrease the number of fine feeding roots. At the Boulder Nursery, by abundant watering and by maintaining the stands at about 100 per square foot in sandy

soil, 2–0[1] western yellow pine has been produced which, it is claimed, is superior to the 1–1 stock.

Watering may be necessary daily, two or three times a week, once in two weeks, or even less frequently, depending on the weather and the nature of the soil. A brownish, dying condition of the seedlings at the Bessey Nursery, called blight for some time and supposedly due to disease, was later found to be due simply to insufficient water. On the other hand, excessive moisture may produce a yellowish, sickly appearance of the seedlings, and plants in this condition do not recover so readily as when somewhat damaged from insufficient moisture.

The same methods of watering are followed after germination as in the pregermination period. Irrigation by flooding is very successfully practiced in the sandy soil at the Bessey Nursery. The practice of watering by hand with a hose can be discarded. While efficient, it is slow and expensive. The use of lawn sprinklers is the most common method. Half a dozen of these judiciously distributed will water an acre of seed beds per day, and will require but a small portion of one man's time for their attendance.

If applied in the late afternoon or evening, the water has an opportunity to soak into the ground with less loss from evaporation than if applied in the morning. It is not always possible to defer watering until late afternoon or early evening, however, and damage from sunscald seldom results from watering at any time of day. The danger of seedlings being scalded by water and sun together if the water is applied in the morning or during the middle of a hot day has, in Forest Service nurseries, been found to exist only with stock of bigtree (*Sequoia washingtoniana*) at the Pilgrim Creek Nursery and black locust (*Robinia pseudacacia*) at the Garden City Nursery.

The periods between watering should be progressively lengthened after the growing season is from one-half to two-thirds over, so as to induce the formation of terminal buds and the hardening of the wood. This is essential. If heavy watering is continued until fall and is accompanied by warm weather, seedlings may continue growth until the season of heavy frosts. The plants are liable to serious damage by frost if they are in a succulent growing condition, and it is obvious that they should be hardened if possible. Withholding water and exposing the plants to sunlight is considered one of the best methods of accomplishing this result.

If the soil is exceptionally dry just before winter sets in, the beds should be given a thorough watering to lessen the probability of winter killing or drying out.

[1] 2–0 stock is that which is grown two years in the seed bed and not transplanted. 1–1 stock is that which is grown one year in the seed bed and one year in the transplant bed.

WEEDING AND CULTIVATING.

Weeding in seed beds is usually a hand operation because the seedlings or rows of seedlings are too close together to permit the use of hand cultivators. Weeds are most easily removed when the beds are moist. They should not be allowed to become so large that their removal will disturb the seedlings, but there is no necessity of removing them when they are very small. Such work is slow and tedious. The removal of weeds improves the growing conditions for the stock by eliminating competition for light and soil moisture.

Cultivation is not practiced extensively in seed beds at Forest Service nurseries, except to check damping-off. Broadcasted beds do not permit it; and where a good water system is installed it is not essential for the purpose of conserving moisture. Watering is efficient and cheaper. In heavy soils which bake and crust after watering, however, cultivation is desirable. It breaks up the crust and insures a better aerated and warmer soil, a condition which tends to the development of larger and better stock. Where the stock is in rows 6 inches or more apart, hand cultivators can be used. Improvised rakes with tines of 8d and 10d finishing nails are sometimes used, but are not very satisfactory. Garden rakes and potato hooks with some of the tines removed, or very small hoes, are quite effective.

WINTER MULCHING.

Some soils are subject to heaving caused by alternate freezing and thawing during the winter and spring. When this occurs plants are liable to be lifted with the soil and a portion of their roots broken off. Thin stands of seedlings and seedlings with shallow root systems are most subject to this damage. When the soil resumes its normal position the plants remain sticking up above the beds or else topple over. It is not a practicable operation to reset them in the ground, and they are usually a total loss. Winterkilling due to excessive drying of the tops of stock when the ground is frozen and the roots unable to secure water is another source of danger. Where necessary, then, precautions should be taken to guard against these two sources of loss.

For protection against heaving and winterkilling good, clean straw, marsh hay, or leaves and twigs free from seed can be used as a mulch. At the Monument Nursery oak brush, cut in August to retain the leaves, gives splendid results for winter mulch on yellow pine. A cover used with success on the Minnesota National Forest is burlap of one thickness. After the first fall of snow of 1½ inches, which sifts in and around the seedlings, nearly covering them, the burlap cover is put over the beds and secured in place by the edges of the seed-bed frames, which are left on the beds over winter. This cover

has the advantage of being easy to put on and remove, and it does not bring weed or grass seed to the beds. The last consideration is a very important one, since weed or grass seed brought in with a mulch is likely to impede nursery operations very seriously and add to their cost. A mulch should not be put on thickly enough to heat and should lie as loosely as possible. If winterkilling is probable, the tops should be covered; if only heaving threatens, just the soil around the roots need be covered. The mulch should be distributed after the ground is well frozen in the fall and removed in the spring before growth starts and as soon as there is little danger of serious freezing at night. It can be prevented from blowing away by covering the seed beds with the protective frames.

When snow comes early in the fall and lies until well into the spring it serves as a cover and usually makes artificial mulching unnecessary. In fact, where there is such a snow cover an artificial mulch in addition is very likely to cause heating and molding of the plants. Where the winters are cold and windy and the snowfall light mulching is generally considered advisable, but its absolute necessity can be determined only by trial. As the operation is expensive it should not be practiced unless essential. In Forest Service work it is practiced with all species only at the Monument, Converse Flats, and Gallinas Nurseries. To prevent winterkilling it is necessary to mulch 1–0 Arizona cypress at the Fort Bayard Nursery and white and Douglas firs and incense cedar at the Pilgrim Creek Nursery. At the Pocatello and Trapper Creek Nurseries mulching is not practiced; but at the former some loss in Douglas fir is experienced from winterkilling, and at the latter a similar loss in western yellow pine has occurred where the snow blew off the beds in midwinter. At the Cottonwood Nursery mulching is attended by a loss from heating and by molding due to the heavy snowfall, but some loss from spring heaving occurs there in thinly broadcasted beds of 1–0 Douglas fir, Engelmann spruce, and Norway spruce, and in drill-sown beds of the last two species. At the Wind River and Boulder Nurseries mulching has been found to be unnecessary, and at the former even harmful. At the Monument Nursery a straw covering damages Austrian pine; and at the old Garden City Nursery it was found that heating and molding was much more likely to occur under straw than under a mulch of leaves.

CARE OF SEEDLINGS IN SUCCEEDING YEARS.

WATERING, WEEDING, AND SHADING.

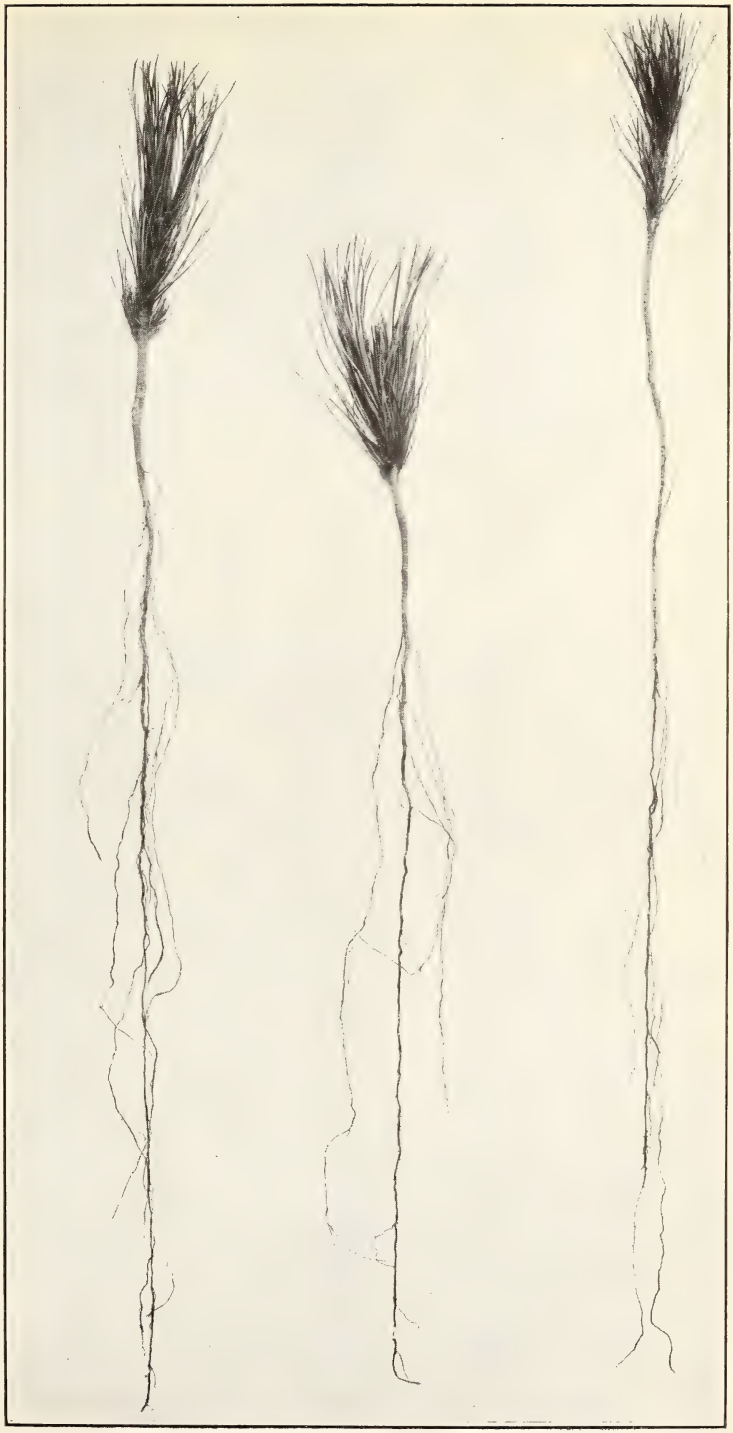
When plants are left in the seed beds longer than one year, the cultural operations are very similar to those of the first year. Watering and weeding are carried on as often as appear necessary. Shading is unnecessary with most species, but not with all. Engelmann

spruce thrives much better if shaded during the second year at the Boulder, Savenac, and Monument Nurseries. The same is true with bigtree at the Savenac, Douglas fir at the Pocatello, and western red cedar (*Thuja plicata*) and Norway spruce at the Wind River Nursery. At the Converse Flats Nursery 2–0 Jeffrey pine and 2–0 incense cedar are shaded, but it is not known to be necessary. At the Page Creek Nursery the shading of sugar pine in its second year in the seed beds has proved undesirable, because the seedlings when shaded reach a size larger than is convenient for transplanting.

ROOT PRUNING.

Root pruning is the cutting off of the lower part of the roots of seedlings without removing them from the beds. Its object is to promote the growth of lateral finely branched roots and a stocky top (Pls. IX and X). It is especially worthy of trial for species with very pronounced taproots or with any species when field planting is to be attempted with seedling stock. It is a practicable operation only when the seedlings are grown in drills or in narrow broadcasted strips. It has not been tried extensively at Forest Service nurseries, and the results of the practice are not yet conclusive.

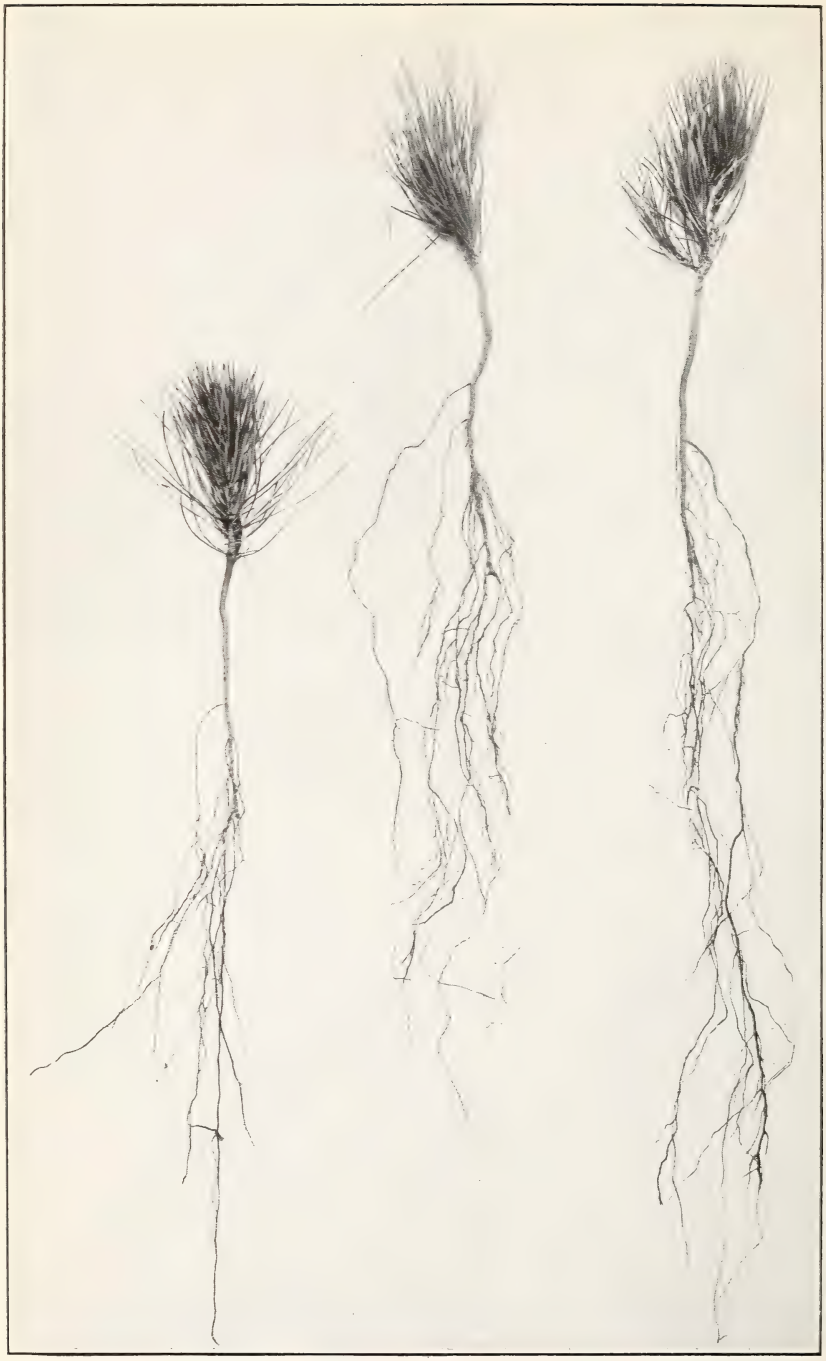
One type of pruner that has been used is a large butcher knife, which is thrust into the ground between the rows at an angle of about 45° and then drawn along so that its edge severs the roots about 6 inches below the surface of the soil. Another is a heavier blade about 12 inches long which is bent below the middle and has its lower cutting end slanted somewhat downward. It has two handles at right angles to each other and about 8 inches apart. Before starting to prune with this tool the soil between two rows of trees is cut with a spade, then the bent end of the pruning blade is dipped into the soil at the end of a row and drawn along as in shaving at any desired depth under the surface. The tool most commonly used is a sharp spade, which is driven into the soil at an angle along one or both sides of a row of seedlings and thus cuts off a portion of the roots. The advantage of using a spade is that it can be operated more rapidly than the other tools and can be used even in stony soils. The other tools are not very efficient under any condition, and are especially impractical in stony ground because they are quickly dulled. In Australia root pruning with spades is practiced even where broadcast sowing is done in long strips 12 to 13 inches wide. Two men with sharp spades work together. Facing each other on opposite sides of a strip, each thrusts a spade into the soil on his side of the row, guiding it at an angle of about 45° downward and toward the center of the strip. The spades meet, practically insuring the severance of the lower portions of the roots of all seedlings in the strip.



F—7058A

3-0 WESTERN YELLOW PINE, BEAVER CREEK NURSERY, WASATCH NATIONAL FOREST. STOCK NOT ROOT PRUNED.

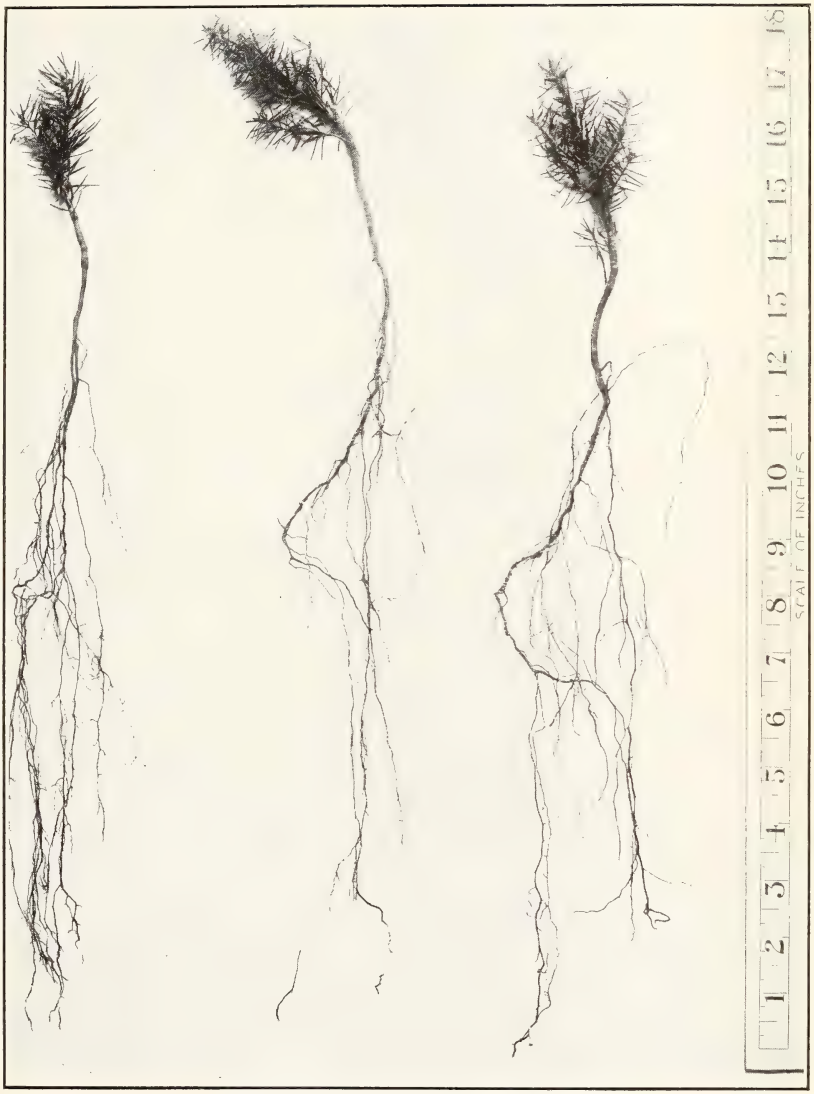
Note better development of roots on root-pruned stock (Plate X).



F–7059A

3-0 WESTERN YELLOW PINE, BEAVER CREEK NURSERY, ROOT PRUNED IN THE SPRING OF ITS THIRD YEAR.

Note better root systems than on unpruned stock (Plate IX).



2-1 DOUGLAS FIR, BOULDER NURSERY.

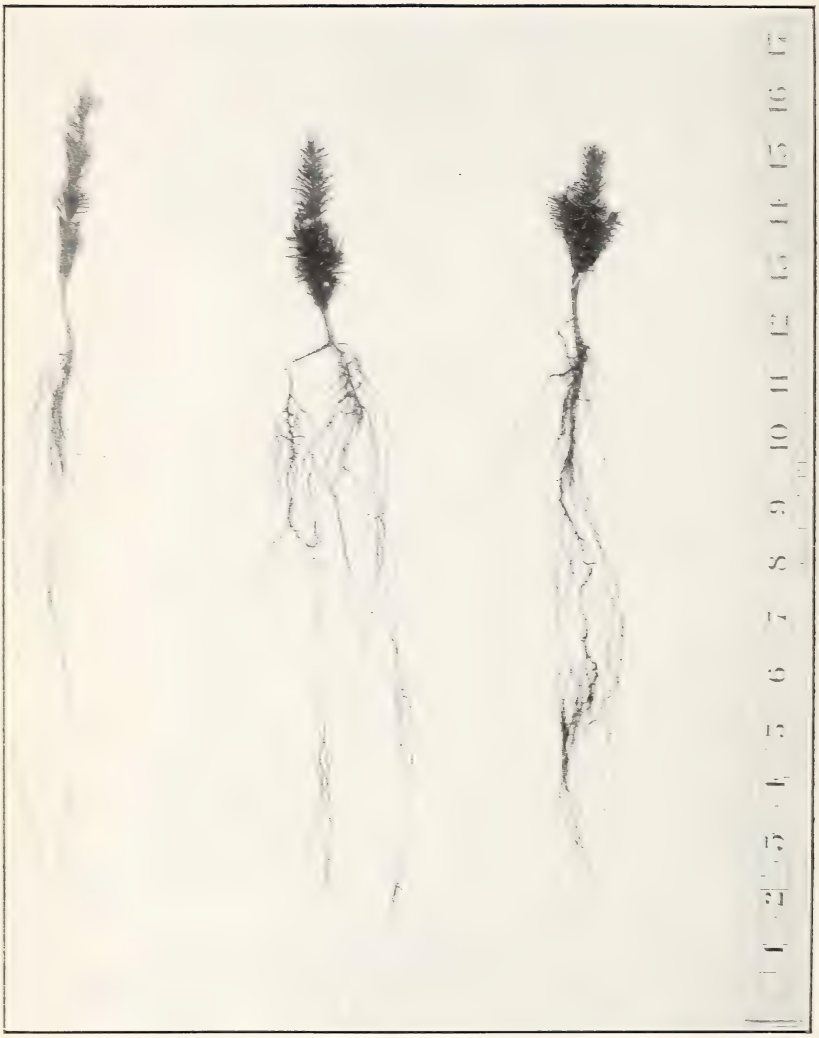
Compare root development with that of same age (3-0) seedling stock (Plate XII).

3-0 DOUGLAS FIR, BOULDER NURSERY.

Compare root development with that of same aged (2-1) transplant stock (Plate XI).

3-0 ENGELMANN SPRUCE.

Compare root development with that of same aged (2-1) stock (Plate XIV).



2-1 ENGELMANN SPRUCE.

Compare root development with same aged (3-0) seedling stock (Plate XIII).

FIG. 1.—WESTERN YELLOW PINE: 1, 1-0 FROM SPRING-SOWN SEED; 2, 1-0 FROM FALL-SOWN SEED; 3, 2-0; 4, 1-1; 5, 2-1; 6, 1-2; 7, 2-2.

FIG. 2.—ENGELMAN SPRUCE: 1, 1-0 FROM SPRING-SOWN SEED; 2, 1-0 FROM FALL-SOWN SEED: 3, 2-0; 4, 2-1; 5, 2-2.

FIG. 3.—DOUGLAS FIR: 1, 1-0 FROM SPRING-SOWN SEED; 2,1-0 FROM FALL-SOWN SEED; 3, 2-0; 4, 2-1; 5, 2-2; 6, 2-3.

F-17520A

FIG. 1.—SIX BEDS AT LEFT SOWN AND COVERED FOR THE WINTER, BESSEY NURSERY.

Bed at right an experiment in the control of damping-off.

F-3-ORT

FIG. 2.—WESTERN YELLOW PINE, BESSEY NURSERY.

Heavy loss due to late spring transplanting.

Root pruning is sometimes practiced during the first season that the plants are in seed beds, but ordinarily it should be done about the time growth is to start, or shortly after, during the second or third season. This gives the plants ample time to recuperate before the end of the season. There is little doubt that by root pruning plants can be produced which will prove more suitable for field planting under adverse conditions than unpruned seedling stock. On the other hand, it is not certain that it will produce stock as suitable for planting on the poorest sites as transplants, and it results in an increase in the mortality of the seedlings. To decrease the possibility of losses the beds should be watered heavily before and again immediately after the operation.

TRANSPLANTING.

In transplanting, seedlings are transferred from seed beds to other beds, where they are given a uniform spacing and much more growing space.

OBJECT AND ADVISABILITY.

Transplanting, like root pruning, has for its object the production of stock which is most likely to succeed in field planting, particularly on inhospitable sites. Its effect is to check height growth of the plants somewhat and to stimulate development of the finer, lateral feeding roots (Pls. XI to XV). In the vast majority of cases such stock is more suitable for planting under unfavorable conditions than seedlings. The conditions on much of the area to be planted on the National Forests are more or less inhospitable; the area is so large that rapid planting is desirable both to cover the ground and to reduce costs; and to conduct the planting operations it is often impossible to secure other than unskilled, careless, and indifferent labor, which means that much of the stock will be poorly planted. These factors make imperative the production of stock best suited to withstand them. Since transplanting achieves this result, its general advisability becomes apparent.

As the greatest single expense of nursery operation, however, comes in transplating, this operation may be inadvisable in regions such as northern Idaho, where experience indicates that success may be achieved with seedling stock. Comparative tests of the two classes of stock for each species and region are necessary to determine the final practice in this regard.

SEASON.

In transplanting, the roots of seedlings lose their contact with the soil of the seed beds and do not function again until they become established in the soil of the transplant beds. During the growing

period the crowns of the seedlings make constant demands upon the roots for moisture. Since the roots are unable to furnish this immediately after transplanting, it is quite essential, in order to prevent losses, to conduct the transplanting operation during the dormant period of the seedlings, which is normally from fall to spring. Snow and the frozen condition of the soil make transplanting impossible during the winter. It must be done, therefore, either in the spring or fall.

Fall transplanting has only a few advantages. There is not the danger, as in spring, of the plants starting growth before the operation is completed; and the transplants are ready to start growth early the following spring and reach a larger size by fall than they would otherwise. On the other hand, fall transplanting is liable to be stopped at any time by early snow or freezing weather; it necessitates double the regular transplant area in case the stock transplanted the previous fall is not yet shipped; fertilizer crops (where green manuring is practiced) can not be turned under in time to decay before transplanting; and the transplanted stock is likely during the winter to be heaved out of the ground or winterkilled because the roots have not taken a firm hold on the soil. Severe losses of fall transplanted western yellow pine at the Savenac, Pocatello, Uinta, and Pilgrim Creek Nurseries have been caused by heaving.

Spring transplanting is, in general, preferable to fall transplanting. The chief objection to it is that growth in the seed beds may start before the transplanting can be completed, causing loss in the transplant beds. The danger can be obviated by working a large transplanting crew and rapidly finishing the operation. Spring transplanting should be started as early as the condition of the soil will permit and then rushed. At the Bessey Nursery the loss in transplanting jack pine and western yellow pine in April was 12 and 17 per cent, respectively, and increased to 30 and 40 per cent in May (Pl. XVI).

If the beginning of growth threatens or starts before transplanting is finished, there is a possibility that it may be checked, but none of the known methods is highly efficient. One method is to heel the plants in the ground in a cool, shady situation, such as the bank of a small stream where there is good, fine soil. A trench deep enough to accommodate the roots and with one sloping side is dug; the plants are spread out along the sloping side in a layer two or three deep with their tops above the surface of the soil and their roots extended to the bottom of the trench; and the loose soil is then thrown over the roots and packed well. If the soil is dry it is watered immediately and at intervals later on. If no shade is available the tops are loosely covered with some such material as burlap or straw and are examined frequently to observe any heating. Fall

heeling in of Douglas fir seedlings for spring transplanting at the Boulder Nursery and of western white pine at the Savenac Nursery proved very unsatisfactory. At the Boulder Nursery the stock appeared fresh and green in the spring, although of a darker color than in the fall. Only a few of the trees had died; but the needles pulled off very easily, indicating a loss of vitality. After transplanting about 35 per cent of the stock died. That which lived started growth very slowly and at the end of the season had developed in size only about one-half as much as seedlings left in the beds over winter (Pl. XVII). An examination of the roots at the end of the growing season revealed the fact that all old laterals had rotted away and that all of those present were newly formed.

Another method is to cover the seedlings while they are in the seed beds with some such material as straw, hay, or shade frames. If straw or hay is used, the seedlings should be examined frequently to detect any heating. At the Fort Valley Experiment Station shade frames are put over the beds after they become snow covered. In the spring these retard for a short time the melting of the snow and the development of the seedlings.

It is possible that an effective method would be cold storage at a temperature just above the freezing point. In Norway, cold-storage houses have been used very successfully for holding plants over in the spring. In the nursery at Softland, on the west coast of Norway, it is stated that Norway spruce can safely be kept in cold storage for 2 months and Scotch pine for 1 month. The plants must not be put into the ice house when wet, however, on account of the danger of molding. No covering whatever is placed over the roots of plants stored in this way. The best plants are secured by having the cellar below the level of the ground. J. Hein's Sons, of Halstenbek, Germany, have their cold-storage house so far below the surface that it is unnecessary to use any ice whatever.

It is much better if none of these methods are necessary. Handling of the plants and exposure of the roots should be avoided as much as possible, for extra handling will manifest itself in greater losses in the transplant beds and will increase costs. In fact, at the Wind River Nursery it is considered better not to remove the seedlings from the beds even if they can not be transplanted until 10 days or two weeks after growth has started. The best results are obtained when the seedlings are transplanted directly from the seed beds.

PREPARATION OF TRANSPLANT BEDS.

Transplant beds should be given practically the same thorough preparation as seed beds, except that hand spading is unnecessary. The area should be plowed as deeply as possible, because this

facilitates transplanting operations. After harrowing and grading, all large roots, rubbish, and stones should be picked up and carted away and the smaller trash raked off. The beds are then laid out, preferably in some rectangular system and with a great deal of regularity, but necessarily in accordance with what the water system demands. Ordinarily the corners of the beds are marked with stakes, and the beds are separated by paths from 1½ to 2 feet wide at the sides and from 2 to 4 feet wide at the ends. The paths at the ends of the beds generally follow a branch of the water system. A convenient size of transplant bed where sprinkling is practiced is 6 feet wide and of any length up to 100 feet. Solid blocks may be planted, particularly when the rows run lengthwise of the beds. Where subirrigation is practiced the beds can not very well be more than 2 feet wide in order to allow for frequent ditches. After being prepared the beds, if not moist, should be sprinkled thoroughly. This settles the soil, facilitates the opening up of the trenches which are to receive the seedlings, and insures a greater success in the transplanting operation.

AGE, SIZE, AND SPACING OF TRANSPLANT STOCK.

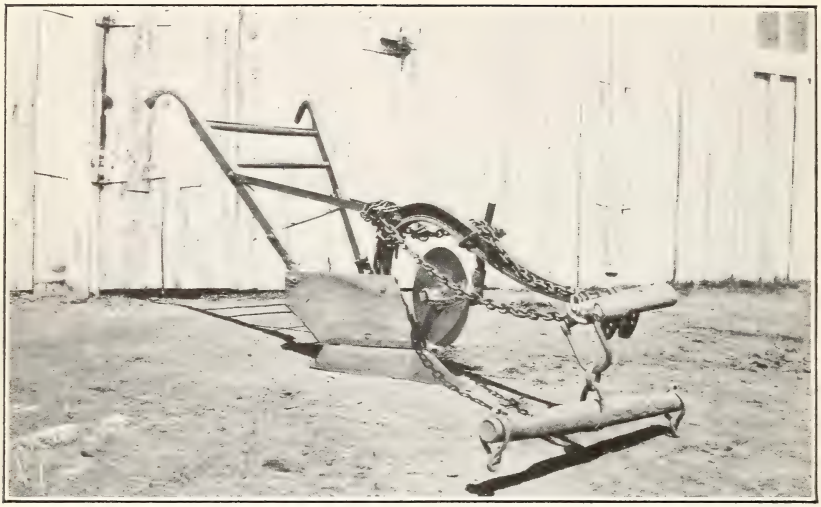
The principal feature which determines at what age stock should be transplanted is its size. It is slower to transplant very small or very large stock than intermediate sizes. Small stock can be handled only slowly and usually has to be left in the transplant beds 2 years before it becomes large enough for field planting, necessitating a transplant area extensive enough to accommodate 2 years' output of seedlings. Large stock necessitates the digging of deep trenches and wider spacing in the beds and should not be used for transplanting unless the resulting transplant stock is particularly well adapted for field planting.

Coniferous seedlings averaging from 2 to 3 inches in height are the most desirable size for transplanting. If possible, such stock should be produced in 1 year. At the end of 1 year in the transplant bed it is usually well enough developed for field planting. Thus transplants suitable for field planting will be produced in 2 years, and this seems to be the end toward which nursery practice should work. Older stock, however, will undoubtedly continue to be superior under some conditions.

At Forest Service nurseries it has not yet been possible to produce in 1 year stock of all species large enough for transplanting. Some species are inherently of such slow initial growth that they will not reach a suitable size; and some nurseries are located where the growing season is so short that sufficient development is not reached in 1 year. The following table shows the age at which seedlings

EFFECT OF "HEELING IN" OVER WINTER.

arded development of both the root system and crown as compared with the tree which as transplanted direct from the seed bed. *A*. Transplanted in the spring direct from ed bed. *B*. Transplanted in the spring after "heeling in" over winter.



F-5-CRT

FIG. 1.—DIGGING PLOW WITH WOODEN MOLDBOARD IN PLACE FOR DIGGING SEEDLING STOCK, MONUMENT NURSERY.

F-26334A

FIG. 2.—TREE DIGGER IN USE AT SAVENAC NURSERY.

of different species are generally transplanted at the Forest Service nurseries, as well as the length of time that they are kept in the transplant beds:

Nursery, location, and species.	Class of transplants produced.[1]
Boulder, Mont.:	
Pinus ponderosa	1–2
Pseudotsuga taxifolia	2–2
Savenac, Mont.:	
Larix occidentalis	2–2
Picea engelmanni	2–2
Pinus ponderosa	1–2
Pinus monticola	1–2 and 2–2
Thuja plicata	2–2
Pocatello, Idaho: Pseudotsuga taxifolia	2–1, 2–2
Bessey, Nebr.:	
Pinus austriaca	2–1 and 1–1
Pinus divaricata	2–1 and 1–1
Pinus ponderosa	2–1 and 1–1
Pinus resinosa	2–1
Pinus sylvestris	1–1 and 2–1
Monument, Colo.:	
Picea engelmanni	2–1 and 2–2, 3–1
Pinus ponderosa	2–1 and 1–1
Pseudotsuga taxifolia	2–1 and 2–2
Fort Bayard, N. Mex.:	
Cupressus arizonica	1–1
Juniperus monosperma	1–1
Juniperus pachyphlœa	1–1
Pinus jeffreyi	1–1
Pinus ponderosa	1½–1, 2–1
Gallinas, N. Mex.:	
Pinus ponderosa	2–1, 1½–1
Pseudotsuga taxifolia	2–1, 2–2
Cottonwood, Utah:	
Picea engelmanni	2–2, 2–3
Picea excelsa	2–1
Cottonwood, Utah—Continued.	
Pinus ponderosa	1–2, 2–1
Pinus sylvestris	2–1, 1–2
Pseudotsuga taxifolia	2–2, 2–1
Beaver Creek, Utah:	
Pinus contorta	2–1
Pinus ponderosa	1–2
Converse Flats, Cal.:	
Cedrus deodara	1–1
Libocedrus decurrens	1–1, 1–2
Pinus jeffreyi	2–1, 1–2, 1–1
Pinus ponderosa	1–1
Pilgrim Creek, Cal.:	
Abies concolor	2–1
Libocedrus decurrens	2–1, 1–2
Pinus lambertiana	2–1, 1–2
Pinus ponderosa	2–1, 1–2, 1–1
Sequoia washingtoniana	1–1
Page Creek, Oreg.:	
Pinus lambertiana	1–1, 1–2
Pinus ponderosa	1–1
Wind River, Wash.:	
Abies nobilis	1–1, 2–1
Larix leptolepis	1–1, 1–2
Picea excelsa	2–1
Pinus maritima	1–1
Pinus monticola	1–1, 1–2
Pinus lambertiana	1–1, 1–2
Pinus ponderosa	1–1, 2–1
Pinus resinosa	1–2
Pseudotsuga taxifolia	1–1
Thuja plicata	2–1
Pinus strobus	1–2

[1] The first figure of each pair indicates the number of years that stock is left in seed beds; the second figure, the number of years that it remains in transplant beds.

More than one class of stock of the same species is often produced at a nursery, partly because the best class of stock has not been fully determined, and partly because of the different conditions met in planting operations. One nursery may supply stock for planting on several varieties of sites on each of which a certain class of stock may be most suitable.

In transplanting at Forest Service nurseries spacings not greater than 1½ inches in the rows and 6 inches between the rows are the rule. This allows ample room for root development and for cultivation by hand cultivators. Though closer spacings than this are practiced successfully at some of these nurseries, they are generally considered inadvisable because the roots become intertwined and may be rather badly damaged when the plants are dug up. The common error is to space plants more widely than is necessary. No harm is done the plants by this practice, but it involves the preparation of a larger transplant area, digging and filling of more trenches, setting of more lines, watering and weeding of a larger area, a more extensive watering system, and, in short, a great deal more work and expense than is

necessary. When stock reaches a large size before or after transplanting, or where there is a deficiency in the water supply during the growing season, wider spacing is justified. It is thought that 1½-inch spacing in the rows is too close for the large 1–0 fall-sown Douglas fir at the Wind River Nursery, and for 2–0 western yellow pine at Fort Bayard.

REMOVING SEEDLINGS FROM SEED BEDS OR "LIFTING."

The first step in transplanting is digging the seedlings from the seed beds. The tool best adapted to this purpose under all conditions is a flat, straight-handled spade. In seed beds of 200 seedlings or more per square foot one man can dig and deliver to the planters from 50,000 to 70,000 plants per day of 8 hours, depending largely on the character of the soil and the care taken. The operation consists simply of shoving the spade at a slight angle into the ground at a distance of about 6 inches from and parallel to the outer row, and then, by backward pressure on the handle, loosening and lifting the seedlings from the soil which surrounds them. In drill-sown beds the practice is often to drive the spade in behind the row of seedlings and pry them away from the remaining stand. When the seedlings are thoroughly loosened and the soil around them is shaken apart, they can be removed without serious breakage of the roots. Two men work to best advantage. While one works the spade the other grasps the tops of a bunch of seedlings, and, by a weaving motion accompanied by a slight pull, removes a bunch of plants at one time. This is work which should be intrusted to one or more carefully selected crews. At a number of the nurseries one man does it alone. Before starting the operation, the soil should be fairly fresh. If necessary, it should be watered to secure this condition. Garden forks are sometimes used instead of spades. They can be handled more rapidly, but are very likely to skin the roots.

At several nurseries horse-drawn tree diggers (Pls. XVIII and XIX) are used for both seedlings and transplants. The principal merit of these is that the trees can be dug very rapidly. The sharp-edged horizontal wedge of the digger shown in figure 2, Plate XVIII, is drawn under the trees at any necessary depth down to 12 inches and loosens a strip of plants about a foot in width. It is somewhat difficult to guide accurately, occasionally coming near the surface and cutting off the roots too closely. Some plants also have their roots badly skinned and the tops of others are trampled by the horses.

The digger shown in Plate XVIII, figure 1, is a modification of a 14-inch stubble plow. The moldboard is cut in half horizontally and the plow is equipped only with the lower part when digging

large stock. For small stock a vertical wooden moldboard is used in place of the steel. This merely serves to push the trees away after they are loosened, but does not cover them.

With the digger shown in Plate XIX the principle of operation is very simple. A wedge-shaped knife 7 feet long, 12 inches wide, and 6 inches thick in the rear is drawn under the beds at regulated depths. As the trees are loosened they are crowded out over the wedge by the forward movement of the implement and are picked from the soil in the rear. The digger is drawn by a horse-operated capstan and steel cable and travels at the rate of 6 feet per minute. The trees are removed in perfect condition. It works better with transplants than with seedlings, because the latter are sometimes covered with soil before they can be removed.

All of these diggers loosen the soil to such an extent that the trees must be taken up very quickly; and since their economic rate of operation is considerably faster than transplanting, some extra labor is required to heel in the seedlings temporarily.

Precautions must be taken to prevent the drying out of the roots. It is well known to nurserymen that conifers are quite sensitive in this respect, but laborers do not generally realize its significance. In semiarid regions the danger is especially great. Buckets, basins, or tubs partially filled with water are sometimes kept at hand, and as fast as the seedlings are dug their roots are immersed in these. All the soil, and it is thought some of the fine rootlets, are washed off by this practice. This has led to a different method at some of the nurseries. Boxes about 3 feet long by 2 feet wide are padded inside with moist burlap or with burlap over moist sphagnum moss. They also contain, fastened at one end of the box, several moistened burlap pads which are used to separate successive layers of trees. As the seedlings are dug they are placed in the boxes in layers with a moist pad between each layer and carried to the transplanting area. In this manner the roots are kept constantly moist, but are not washed.

The importance of not subjecting the roots of conifers to exposure at any time can not be emphasized too strongly. Coniferous tops remain green for a long time after the roots are dead, and their appearance can not be taken as a criterion of the condition of the stock. An exposure of even 2 or 3 minutes, particularly on a windy or very hot day, may prove fatal; and mortality in transplant beds or in field planting may be due to lack of care in this respect rather than to improper methods of transplanting or field planting. At the Boulder Nursery experiments in exposing seedlings of Douglas fir to the sun for periods varying from 3 minutes to 4 hours resulted in a loss in the transplant beds of 5 per cent when the exposure was for 3 and 6 minutes, of 8 per cent

with a 10-minute exposure, of 12 per cent with a 15-minute exposure, of 40 per cent with a 20-minute exposure, and of 90 per cent with a 4-hour exposure. While some stock survived even after 4 hours' exposure, it sustained in an increasing ratio a serious retardation in growth as the period of exposure increased.

ROOT TRIMMING.

After being removed from the seed beds the roots of seedlings may be trimmed or pruned to a length of 6 or 7 inches before they are transplanted. A sharp knife, scissors, hatchet, or meat ax is suitable for the operation. Usually a bunch of seedlings are gathered in one hand and the roots of all pruned at the same time. In this operation special care should be taken to remove all badly skinned, broken, or diseased roots.

Root trimming facilitates transplanting operations, because the trenches do not have to be dug deeply to receive the seedlings; and to some extent it promotes the formation of a compact, well-developed root system. On the other hand, if it is carelessly done, the roots of some seedlings are likely to be cut so short as to injure them and cause greater losses in the transplant beds. Moreover, in digging seedlings for transplating it is seldom, unless special care is taken, that roots longer than from 8 to 10 inches are retained. These are not too long for rapid and successful transplanting. At the Boulder Nursery the conclusion has been reached that with Douglas fir root pruning makes the stock less desirable for planting on areas east of the Continental Divide, because it induces the formation of a root system too superficial for best results in planting in this dry region. In general, where the seed-bed operations are properly carried out root pruning is unnecessary.

GRADING SEEDLINGS.

Seedlings which are badly damaged in digging and those which have very poor root systems or poorly developed tops should not be transplanted. Their use makes certain a greater loss in the transplant beds and the production of a mixed quality of transplant stock, some of which at the end of the regular rotation for the species is too poorly developed for field planting. Such seedlings should be discarded or, at most, transplanted in beds separate from the better stock. The discarding or grading can be done either when the seedlings are being removed from the seed beds or, better, as they are threaded into the transplant boards. In the latter case men with good judgment in this matter will have to be assigned to the threading tables. The importance of discarding or grading out such stock justifies the operation being practiced at all nurseries.

TRANSPLANT TOOLS.

Dibble.—A dibble is a round or dagger-shaped, straight steel tool with a blade about 7 inches long and from ½ to 1 inch wide and usually provided with a handle. Its use is described later.

Trenching tools.—Spade: For opening the trench in the transplant bed to receive the seedlings the spade is most commonly used and is the best all-around tool for the purpose. With it, either a wedge-shaped trench or an excavation one side of which is vertical and the other sloping can be made. Moreover, it is better adapted to a variety of soils and for digging the trench to any desired depth than other tools.

Hand trencher: The hand trencher is described as follows in Volume X, No. 1, of the Forestry Quarterly:

> The hand trencher consists of two plates of steel 7 inches wide and 26 inches long, welded together along one edge and drawn out to a thin cutting blade. The opposite edges of these plates are separated about 1 inch, allowing space into which three pieces of ¾-inch pipe, slightly flattened, are inserted and riveted. One piece of pipe is inserted in the center and the other two at 2½ inches from the ends of the plates. All are brought together in a cross or four-way pipe connection, 8 inches above the plates. Into the upper opening of the cross a piece of pipe 20 inches long is fitted, supporting a toe into which 6-inch pieces of pipe are screwed forming a complete T-handle. To obviate a second bending of the pieces which extend from the ends of the blade to the handle, nipples and angle connections may be used. The trencher weighs from 18 to 24 pounds, depending on the thickness of steel used in the blade, and should be made by any blacksmith at a cost of from $3 to $5.
>
> To make a trench the trencher is put in proper position and weight put on it by placing the foot on the top of the blade. The operator then works the handle to and from his body as the blade sinks into the soil, making a trench about 2½ inches wide at the top and any desired depth depending upon the length of the roots of the seedlings to be transplanted. For a planting board 6 feet or 6 feet 3 inches long the trencher must be set into the bed three times in the same line. A 36-inch trencher requires two men to handle it while one man can handle a 26-inch implement. This tool leaves a trench with smooth sides and can be used very satisfactorily in almost any nursery soil.

This hand trencher was devised by Mr. William H. Mast for use at the Bessey Nursery, where the soil is very sandy, light, and easily worked. Here this tool has given very good satisfaction. It undoubtedly will do likewise in any other nursery where the soil is light, loose, and free of rocks and débris. It is also used successfully in the rather heavy soil of the Monument Nursery. There the tool used is only 12 inches wide and 8 inches high and has a wooden instead of a pipe handle. One very decided advantage which the trencher has is that the operation of opening up each trench in a bed packs the dirt firmly around the preceding transplanted row of seedlings and thus counteracts carelessness in this respect by the planter.

Broadax: The broadax has been used for trenching, but is unsatisfactory. The cleft style of trench only can be made with this tool

and it is not so suitable for the purpose as the spade. It requires a more skilled operator, the depth of the trench is limited by the depth of the blade, and it is more difficult to run the lines straight.

Plow: Where the transplants are in long rows a plow has been tried for making the trenches and has worked admirably. The plow is of the small one-horse type and is equipped with an 8-inch (depth of trench) landslide, a short moldboard, and a shield to divert all the soil toward the moldboard side.

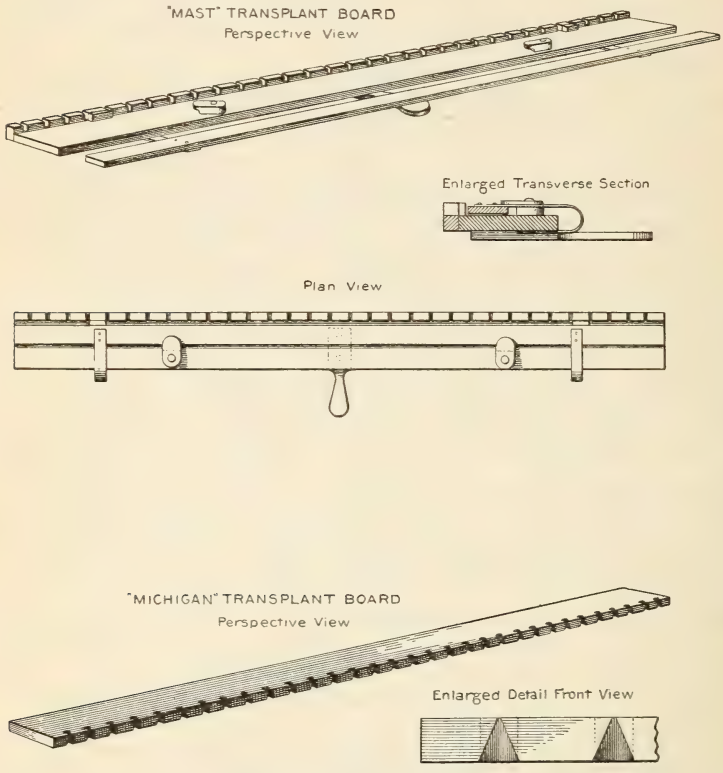


FIG. 6.—Transplant board.

TRANSPLANT BOARDS.

Transplant boards are all essentially the same in principle. There are two distinct types, the basis for the distinction being that in one, exemplified by the "Mast board," so called from its designer, Mr. William H. Mast, seedlings are threaded into the board from a bench and afterwards lowered into the trench; while in the other, exemplified by the "Michigan board," seedlings are threaded into the board as it lies on the ground projecting over the trench (fig. 6). With the first board a crew of from 5 to 7 men (2 planters, 1 or more trench-

ers, and 2 threaders) is usually employed; with the second board a crew of 2 men perform the operation.

The "Mast board" is described in Volume X, No. 1, of the Forestry Quarterly, as follows:

> The planting board consists of a 5-inch board 6 feet 3 inches long with a handle attached in the middle and extending in the same plane as the surface of the board. On the lower edge a piece 1½ inches wide is nailed flush with the back of the first board and its front edge beveled to about one-half inch in thickness. Into this edge 50 notches are sawed 1½ inches apart (when the trees are to be spaced 1½ inches apart in the transplant beds), one notch falling three-fourth of an inch from either end of the board. These notches are slightly wider at the bottom than double the saw-kerf, or about one-eighth of an inch, and should be made smooth with emery cloth or a sharp knife and rounded at the outer edge to admit of threading the trees into them easily. Before sawing the notches the parts between them should be strengthened by driving one or two 1¼-inch brads through them. The inner parts of the notches are flush with the face of the vertical board, so that when the trees are threaded into the notches they lie flat against the face of this 5-inch board. A slat placed over them and fastened by two buttons holds the seedlings in place while the board is being carried from the threading table to the trench. A loop or binding of tin over one end of the board forms a pocket into which the end of the slat is placed before being buttoned down; this helps to hold it and prevents it from slipping past the end of the board when placed on the trees. The slat fits loosely enough so that it does not crush the stems of the seedlings when it is buttoned down. The buttons are made with a slight bevel, so that when turned only partially over the slat they do not hold it so closely as when turned at right angles to it; this allows for handling both large and small stemmed seedlings with the same degree of efficiency.

At the Bessey Nursery the slat which holds the seedlings in place is now fastened to the transplant board by means of leather hinges. With this scheme the binding of tin over one end is unnecessary.

The "Michigan" planting board consists of a 6-inch board, 7 feet long and 1 inch or more in thickness, in which a row of one-fourth-inch holes are bored one-half inch from the edge at the interval of spacing desired in the transplant beds. A narrow, wedge-shaped slot is then cut from the edge into the hole and all rough edges and corners smoothed off. The point of the wedge is upward, so that any dirt that gets in the holes or slots may fall through without clogging and pulling out the seedlings when the board is removed. Before the slots are cut the edges of the board between them are reenforced with lath nails.

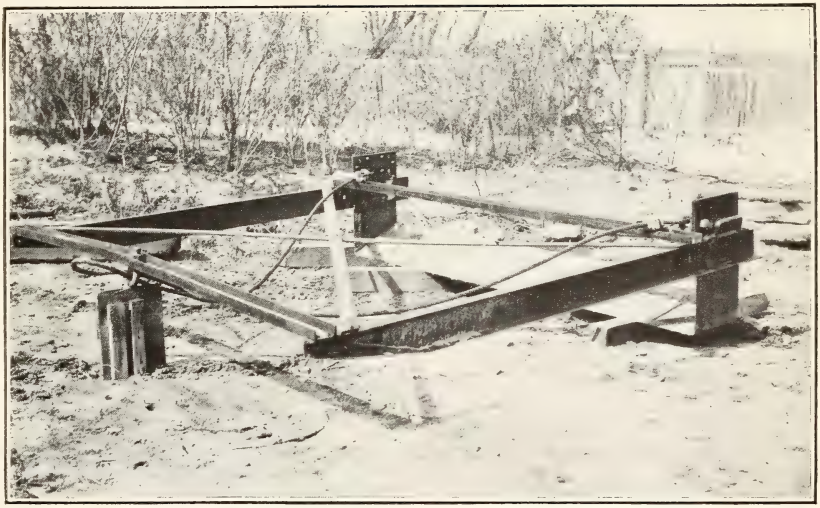
Both of these boards are efficient, but each has some advantage over the other. The "Michigan board" has been used most extensively at the Wind River Nursery and has been constructed there at a cost of 37 cents. The "Mast board" is more complex, but it also is quite easy of construction and has been made for 56 cents at the Bessey Nursery. The "Mast board" can be used with any sort of

a trench; the "Michigan board" only with trenches which are constructed by excavating the soil. A single "Mast board" is better adapted for use with all sizes of seedlings, if they are of uniform development, than a single "Michigan board." With the "Mast board" the most efficient man for trenching, threading, and transplanting can be detailed to those duties, while with the "Michigan board" each man performs all of the operations. When the "Mast board" is used with seedlings which are not of even development, the smaller ones get displaced easily or lost out or, in the process of tamping the dirt around the roots, are pulled down too deeply into the trench. With both boards there is some danger of pulling the tops off the seedlings as they are released, but this is more pronounced with the "Michigan" than with the "Mast board." Under the greatest variety of conditions it seems that the "Mast board" is preferable to the "Michigan." Where the danger of drying out the roots of the seedlings is very great, the "Michigan board" should prove the better of the two. Using either board an efficient crew can average from 4,000 to 5,000 plants per day per man, and a record as high as 8,500 plants has been made at the Uinta Nursery with a board of the Mast type.

The "Yale board" is a modification of the Mast board, differing from it principally in that the slat which holds the seedlings in place is attached to the two hinged handles. The slat swings over to rest against the seedlings in much the same manner as when leather hinges are used with the "Mast board." The Yale type of board used at the Savenac Nursery is provided with spring clamps which press the slat against the seedlings and make knobs or buttons unnecessary. These clamps are conducive to greater speed in the transplanting operation. The two-men crews using these boards average 12,000 trees per man per day at this nursery.

Another board which is cheap, efficient, and used extensively is made simply by tacking a thin hardwood strip 2 or 3 inches wide on the flat undersurface of a 5 or 6 inch board, so that its edge will project about an inch beyond the edge of the wider board. In this projecting edge notches are cut to receive the seedlings. When threaded, the seedlings are held in place by means of strong elastic twine stretched in front of them from one end of the board to the other.

Planting boards are usually 6 feet long, to conform to the most common width of transplant beds. At the Converse Flats Nursery boards 8 feet long and at the Savenac Nursery boards 8½ feet long are used. At the latter nursery the rows run lengthwise, and the greater length of board is quite advantageous.



F-6-CRT

FIG. 1.—TREE DIGGER IN USE AT BESSEY NURSERY.

Weight approximately 400 pounds.

F-7-CRT

FIG. 2.—TREE DIGGER IN ACTUAL OPERATION.

Four men are required to pick the loose trees from the soil as it breaks over the rear of the knife.

F-8-ORT

FIG. 1.—OPENING TRENCH WITH HAND TRENCHER, LOWERING TRANSPLANT BOARD OF SEEDLINGS INTO TRENCH. THREADING TABLE AT THE LEFT.

F-14232A

FIG. 2.—TAMPING SOIL AROUND ROOTS OF SEEDLINGS.

TRANSPLANTING OPERATIONS.

METHODS.

Transplanting methods in Forest Service nurseries are uniform to the extent that a transplanting board is used at all of them. Such boards have proved very efficient, rapid, and successful, even though very trying weather conditions prevail at the time of transplanting. The old method of using a dibble and transplanting each seedling as a distinct operation has been almost entirely discarded. It is accordingly only briefly described here.

Dibble method.—The operator inserts the dibble in the soil of the transplant bed and pries it back and forth or gives it a quarter turn to form an opening large enough to receive a seedling. The roots are then inserted in the hole and the dibble again thrust into the ground near the plant and pushed toward it to close the opening and pack the dirt around the roots. If the spacing in the transplant beds is close enough, this second thrust of the dibble can be made at the point where the next plant will be set and the operation of closing up the preceding cleft will at the same time open one for the receipt of the next plant. By the use of this system one man can transplant from 1,100 to 1,500 seedlings per day. It has proved a very inefficient method in that the size of the opening does not permit the roots to assume a normal position when the plant is inserted. Crooked, distorted roots and heavy losses in the transplant beds result.

Transplant board method.—Depth of trench: The trench should be deep enough so that the roots will not be curled up or bent over at their ends. Such a position is not conducive to the formation of good root systems. Roots bent unnaturally in this manner, moreover, are likely to break when the plants are dug or when planted in the field.

Setting seedlings in the soil: When the "Michigan board" is used the process of setting seedlings in the soil is quite simple. Laying the transplant board across the bed, a trench whose side next the board is vertical is excavated along its edge, each man of the 2-man crew covering half the distance. The seedlings are threaded into the holes, half by each man; the loose soil is then drawn in, a portion at a time, and packed against the roots until the trench is filled up level. To draw in and pack the soil against the roots a piece of inch board 6 inches wide by about 8 inches long is efficient. The transplant board is disengaged from the seedlings by a tilting forward and backward sliding movement.

The board is next placed with one of its edges flush with the row of seedlings just transplanted, another trench is dug along its other edge, and the operation repeated. A mark across one end of the board is kept in line with a heavy twine stretched along the edge of the bed, which is thus kept practically straight.

When a type of planting board like the "Mast board" is used, the process of transplanting is more complex in that the operation is performed by a larger crew, usually of five or more men, and each distinct part of the operation is performed by a portion of the crew assigned to it. In operations at the Bessey Nursery two men are employed in threading seedlings into each of the transplant boards, one man is employed in trenching with the hand trencher, and two men can do the planting. The threading is usually conducted on benches which are provided with canvas or burlap tops for shade and are placed as close as possible to the transplant beds. A shelter of some sort during threading operations is essential. The roots are kept moist by covering them with damp moss until placed in the boards and the threaders only strive to keep even with the planters. To have several threaded boards ahead of the planters means exposure and possible damage of the roots. It is quite generally maintained that the speed of transplanting depends upon the speed of the threaders; accordingly, men who are nimble with their fingers should be selected for this operation.

To expedite trenching, from 3 to 5 beds are carried forward at the same time. A trench is made in the first bed, then in the second, then in the third, and so on, the man making the trenches in each case being out of the way of the planters who follow closely behind him. The planters in their turn are out of his way when he returns to the first bed to make the next trench in it. A cord is stretched across the ends of the beds to be planted, so that the first row of each is in line with the first row in the others. The successive rows are kept equidistant by guide boards lying between each two beds on which lines are marked at intervals of 6 inches. Each trench is started in line with a mark on the board at one side of the bed and is finished at a corresponding mark on the board at the other side.

Two men can work together to advantage with planting boards 6 feet wide or wider. Upon receiving a board threaded with seedlings the planters face the trench and lower the roots into it with a slight swinging lateral movement to insure their assuming a natural hanging position. The soil in front of the board is then thoroughly tamped against the seedlings, the slat holding the seedlings in place is removed, the board rotated on its edge toward the planters, and the soil behind the seedlings also thoroughly tamped toward them (Pl. XX). By lifting the board now the seedlings are released and the operation is completed. Immediately after each day's transplanting operations are completed the beds should be thoroughly watered. Neglect of this operation has caused severe losses.

The size and disposition of the crew may be varied considerably to meet different conditions. Two men may be needed for trenching, particularly if the soil is not loose in character or if spades are

used for the operation; and one man may be sufficient for planting. At the Savenac Nursery, where the trenches are prepared with a plow, two men, one a threader and the other a planter, comprise the crew. This is a matter to be determined during the course of the work.

Pot method.—Where field planting is of doubtful success because of extremely trying weather conditions, as in southern California, or where summer planting appears desirable, as in Arizona and New Mexico, the method of growing plants first in seedling flats and then transplanting them to paper pots has been tried. Both plants and pots are later set out in the field. The method of transplanting is simple. Paper pots 2 inches square by 8 or 10 inches deep are the preferable size if the plants are to be left in them for 1 year only. If they are to be left for 2 years a pot 3 inches square by 8 or 10 inches should be used. The transplanting is carried on under shade. Seedlings are removed one at a time from the flats and planted in the pots in the same manner that gardeners employ with vegetable or house plants. A hole is made with a dibble, the roots inserted, and the soil firmed around them. Watering follows the operation of transplanting.

This method of transplanting can be justified only where it is certain that only through it can stock be made to succeed under adverse field conditions, and further, that it is necessary to plant where such field conditions exist. Such transplanting is slow, one man being able to prepare soil and transplant only from 600 to 750 plants per day. The pots cost about $3 per thousand. Crates to hold the pots have been built for about 40 cents each. Until experience absolutely proves the superiority of such plants, this method of transplanting should not be practiced extensively. It has been given a trial both in California and Arizona nurseries. At the latter it has been abandoned because better results in planting have not been secured with the stock. At the former, indications are that such stock may prove the most successful.

FACTORS AFFECTING COST.

A number of factors influence the cost of transplanting. Size of stock is one of these. The use of very small stock may materially increase the cost of the operation. Thus, at the Boulder Nursery in 1911 the cost of transplanting medium-sized stock, the preferable size, was $1.10 per thousand; small stock, $1.35; and large stock, $1.65. Large stock often necessitates wider spacing, which means the digging and filling of more trenches to accommodate the same number of seedlings, and small stock can not be handled rapidly. At the Fort Bayard Nursery the cost of transplanting western yellow pine with a spacing of 3 inches in the rows was in one case

nearly 1.9 times and in another 1.5 times as much as where a 2-inch spacing was followed. At the Wind River Nursery the crews averaged 5,000, 3,800, and 3,300 trees per man per day when $1\frac{1}{2}$, $2\frac{1}{2}$, and 3 inch spacings in the row were used respectively.

On poorly prepared or heavy soils costs will be greater than on well prepared or loose soils. Thus, at the old Garden City Nursery, in a heavy soil, the crews averaged 3,000 plants per man per day, while in the near-by Kansas Nursery, whose soil is a pure sand, the average was 4,000 per man per day. The method followed in transplanting, whether by the dibble or by one of the various forms of transplant boards, will influence the cost. The character of the crew or crews will also be a factor. Good crews sometimes average from one-fourth to one-half more plants per day than poor ones.

CARE OF TRANSPLANTS.

In the transplant beds the trees are given their final preparation for field planting, and the care given them has much to do with their success under field conditions. The root development can be controlled somewhat through watering, and this is the most important feature of transplant growth. Shading, cultivation, weeding, and care in winter need some attention.

Watering.—Immediately following transplanting, and for a period of 3 weeks thereafter, transplants should be watered liberally. During this period the plants should become pretty well established and start growth. Watering can then be decreased, but for the greater part of the growing season the soil should be kept fresh within a short distance of the surface. At the Monument Nursery western yellow pine at first requires more water than either Engelmann spruce or Douglas fir, but later the opposite is true. Because the roots are confined to a small amount of soil, potted transplants must be watered more frequently than those in beds.

It has been pretty well proved that in a soil which is kept fresh near the surface there will be a good lateral development of the roots in this zone, and that such stock is in the majority of cases more suitable for field planting than if the greatest development of the root system occurs at the lower end. In digging transplants for transferring to the field the lower portion of the roots is almost certain to be cut or broken off. The result is that when a plant whose main root development has been at the lower end is placed in its new habitat, it must develop new feeders before it can fully avail itself of the water and plant food available. It is desirable, therefore, that the main development be kept within the first 8 to 10 inches of depth, and watering should be conducted with that end in view. By keeping the soil of the transplant beds fresh near the

surface, western yellow-pine stock is now being produced in Arizona, which succeeds when planted even under the arid conditions obtaining in that country during the spring of the year. This success is a good criterion of the stock's merit, particularly as very poor results had previously been obtained from field planting with the ordinary run of stock without pronounced lateral roots developed near the surface. Little or no watering for the purpose of hardening the trees to the conditions which obtain in the field has not yet, in Forest Service operations, produced more successful stock for field planting than well-watered stock. At the Bessey Nursery, in fact, much better results have been secured in field planting with stock which was watered in accordance with the regular nursery operations than with that which was not watered at all.

Any of the methods of watering applicable for seed beds may be used, but sprinkling by hand with a hose is expensive and scarcely practicable. Irrigation or the use of garden sprinklers is almost essential. Because of the large size of the transplants, irrigation is much more feasible than in seed beds, and because of its rapidity it is a method which should always be given consideration. At the Bessey Nursery, where flooding is practiced, the transplant area is watered in sections. Areas of one or more beds are banked up with soil around the edge, and water is then conveyed to them from the 4-inch main pipe line through large canvas irrigating hose. When one section becomes flooded the hose is moved to the next one. One acre can be covered in six hours. At the Savenac Nursery, where ditch irrigation is used, the water is controlled, as in agricultural projects, by a system of headgates and by temporary mud dams for diverting it from one ditch to another (Pl. XXI). On steep grades some wooden troughs, with small holes bored through at intervals to allow the water to escape to the ditches, are employed. It is claimed that one man can water 3 acres per day. Ditch irrigation is practiced also at the Fort Bayard Nursery. There a system of galvanized-iron troughs to carry the main body of water is being tried. Opposite each ditch in the transplant area these troughs have openings the size of which can be regulated by means of a sliding cap. The amount of water turned into each ditch can be controlled easily and absolutely.

A single watering by any method should be thorough enough to soak the soil to a depth of about a foot. Experience indicates that it may ordinarily be conducted at any time of the day without injury to the plants, except at the Pilgrim Creek Nursery, where sprinkling is practiced, and where it seems to be necessary to water bigtree (*Sequoia washingtoniana*) in the evening rather than in the morning.

Shading.—Shading is almost wholy unnecessary in transplant beds, except in a few cases; and because of the expense involved, if for no

other reason, it is decidedly undesirable. If plans will permit it, species should not be grown at a nursery where it is necessary to give them shade during the transplant stage. Some trees, however, such as spruce, true firs, redwood, and western red cedar, have, wherever grown so far, appeared to need shade when first transplanted. Douglas fir transplanted when only 1 year old has shown a need for shade at the Beaver Creek Nursery in Utah, at the Pocatello Nursery in Idaho, and at the Gallinas Nursery in New Mexico. Engelmann spruce transplants do better if shaded, both at the Monument and Wind River Nurseries; and the same is true of western red cedar at Wind River.

Shading of transplants is expensive. It stimulates height growth, which is normally undesirable in stock for field planting, and the stock produced is not so well fitted for enduring the more trying conditions to be met in the field as that grown in full sunlight. A possible exception to this is to be found in the case of Douglas fir for planting under aspen in Utah and southern Idaho. Here it is thought, but not proved, that stock shaded in the transplant beds may be preferable for field planting.

Cultivation and weeding.—Cultivation serves the same purpose in transplant beds as in seed beds; that is, it breaks up a crusted surface soil, conserves soil moisture, and cuts down the amount of weeding and watering necessary. At the old Garden City Nursery only one-third as much watering was necessary with cultivation as without it. Cultivation is best carried on as soon after watering as a crust begins to form on the soil, and it is a particularly desirable operation in heavy soils. On loose, sandy soils it is not so essential, but is beneficial even there. It can be carried on rapidly with a wheel cultivator, by the use of an ordinary potato hook whose center tine is cut out, or by some other similar tool which straddles the rows (Pl. XXII).

Weeding should be done as often as is necessary, which is usually from three to four times a season. Pulling by hand is the most effective method, but some implements are good, such as narrow hoes or tools with sharp V-shaped edges. At the Wind River Nursery the chief weeds are brake fern and blackberry vines, which can not be pulled very well without damaging the trees. They are accordingly cut off below the ground. For this purpose a weed cutter was originated from one of the straps of steel which reinforced the shank of the handle of a worn-out shovel. This short, half-tubular, curved piece of steel with a sharp V-shaped notch filed in the end of it was riveted to the end of a broom handle. Experience has shown that this tool is very well adapted to the work.

Mulching during winter.—Transplants in general need no attention during the winter. Occasionally mulching is practiced when

there is the possibility of heaving or of winterkilling, but after a season's growth in the transplant beds the stock is usually so well rooted that there is little danger from the former source. This is particularly true in nurseries of sandy soils and in those where the snowfall comes early and is abundant and stays until fairly late in the spring. If artificial mulches are necessary, the same ones may be used as in the seed beds. At the Gallinas, Monument, and Converse Flats Nurseries mulching of transplant beds over winter is necessary.

At the Monument Nursery a light covering of straw held in place by oak brush is sufficient for western yellow pine. For Douglas fir the space between the trees is filled with leaf mulch, after which a layer of lath slatting is rolled over the beds to bend down the long shoots. This is covered with a thin coat of leaf mulch, which is held in place by oak brush. Engelmann spruce is covered with leaf mulch, which is held in place by brush. Heavy winter winds make mulching necessary at this nursery. At the Converse Flats Nursery mulching is necessary to prevent heaving, because fall transplanting is practiced. Pine needles are distributed between the rows to a depth of about 3 inches.

Heights, in inches, of different classes of nursery stock.

Region and species.	Class of stock.					
	1–0[1]	1–1	1–2	2–0	2–1	2–2
Rocky Mountain:	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Pseudotsuga taxifolia	1 to 2	.....	4	2 to 5	2½ to 6	5 to 6½
Larix occidentalis	1 to 1½	2 to 5	.....	.....	.....	.....
Pinus divaricata	1 to 3	5	15	5	10	.....
Pinus jeffreyi	1½ to 3	.....	.....	2 to 5	.....	.....
Pinus monticola	1 to 1½	.....	4	.....	.....	6
Pinus ponderosa	1 to 3	2 to 4	5 to 16	2 to 8	4 to 10	9½
Picea engelmanni	½ to ¾	.....	4	1 to 1½	2½ to 3	4
Pacific Coast:						
Pseudotsuga taxifolia	½ to 5	4 to 9	.....	6 to 10	.....	.....
Abies nobilis	2	2 to 4	.....	.....	.....	6 to 10
Abies concolor	½ to 2	2 to 6	.....	6 to 8	.....	.....
Larix occidentalis	1	.....	.....	2 to 8	.....	.....
Pinus jeffreyi	2 to 4	4 to 7	6 to 8	5 to 6	.....	.....
Pinus monticola	1½ to 2	1½ to 3	.....	2 to 4	.....	.....
Pinus ponderosa	2 to 4	2 to 8	6 to 12	5	4 to 7	.....
Libocedrus decurrens	2 to 3	.....	9	.....	.....	.....

[1] The first figure of each pair indicates number of years stock remains in seedbed; second figure, the number of years in transplant beds.

LOSS IN TRANSPLANT BEDS.

Losses in transplant beds should not exceed from 5 to 10 per cent. They are often greater, but they can be reduced to a minimum by careful transplanting, the choice of stock of the right age and size for transplanting, grading, care in taking up the plants so as not to injure the roots, keeping the roots constantly moist, reducing the time between lifting and transplanting, little or no root trimming,

soaking the beds thoroughly immediately after transplanting, and by conducting the operation as early in the spring as the weather will permit. Losses will unquestionably be greater with some species than with others. Thus sugar pine and Arizona cypress have been found to be difficult trees to transplant without rather severe losses.

REMOVAL OF PLANTING STOCK FROM NURSERY.

DIGGING.

As far as possible, stock for shipping should be taken up as packing progresses. The transplants are dug with a spade or horse-drawn tree diggers in the same manner as seedlings. The number which can be dug in a day depends upon the method, the size of the stock, the character of its root system, the nature of the soil, the weather, and the spacing. At the Wind River Nursery, where the soil is fairly loose and the spacing 1 to 1½ by 6 inches, 2 men have dug 1–1 Douglas fir at the rate of 40,000 per day. This number is large, and as speed is conducive to carelessness the maintenance of such a rate should not be attempted. An average of 15,000 per day for 2 men digging only should be easily possible, making the cost of the operation about 25 cents per thousand. Where grading and counting are practiced in conjunction with digging, the rate is decreased. With horse-drawn tree diggers the rate can be increased one-half or more. As the trees are removed they can be heeled in right back of the diggers and afterwards counted, graded, and bunched under cover of a building, or these operations may be performed by an additional man as fast as the trees are lifted. The bunches of each class of stock should be uniform in shape and size and not too large, and should contain equal numbers of plants, ordinarily from 25 of the larger to 150 of the smaller trees. These bunches are tied loosely, and then heeled in if packing is not being carried on at the same time. If the weather is very dry while counting is in progress, the roots should be sheltered and immediately covered with damp soil, burlap, or moss as soon as they are bundled.

GRADING.

Grading stock requires about twice as much time as when extra plants are included to make up for the average number of culls per bunch. The time saved by this latter method may be worth decidedly more than the value of the extra trees which might be included in a shipment through error in overestimating the number of culls. One man can count, bundle, and tie on an average about 12,000 trees per day, making the cost approximately 21 cents per thousand. Where close grading is considered essential, as in Arizona and New Mexico, it can be conducted more effectively at a nursery than by a planting

crew, and the culls should accordingly be discarded before shipping. Where close grading is not considered necessary, as in the Pacific Northwest, strict counting of the stock as it is dug may not be essential. At the Wind River Nursery the practice is followed of estimating closely the stock in each transplant bed and supplying definite amounts for shipment from these estimates. This practice has been largely responsible for reducing the cost of distribution from $1.31 to $0.855 per thousand.

PACKING.

The general practice in Forest Service nurseries is to tie the trees in small bunches. In this shape they are easier to handle both at the nursery and at the planting site, and it has been thought that they withstand better the rough treatment incident to shipping and to packing on horses. That this bunching is unnecessary is shown by experience at the Monument Nursery. Here packing is conducted in the usual manner, except that the trees are spread out in thin successive layers. Moss can better come in contact with all roots than where the trees are bunched, and trees packed thus have withstood shipment for long distances and arrived in good condition.

The main points to be given consideration in packing for shipment are to minimize the possibility of the roots drying out and the tops heating while en route. To avoid this, the plants are shipped in open crate-like boxes which provide ample ventilation for the tops; and damp moss, preferably sphagnum because it holds moisture best, is packed around the roots. At the Savenac Nursery, the sawdust from a shingle mill has been found very satisfactory for packing. Trees are usually placed in the crates in tiers, the tops of one tier tōward one end of the box and the tops of the next tier toward the opposite end, the roots of the successive layers overlapping. A strip of moist burlap as wide as the space covered by the roots of the plants should be spread in the bottom and extend up along the center of both sides of the crate. On this a layer of damp, well-drained moss is placed and then the first tier of transplants. Another layer of moss is now placed over these roots and chinked in between them, but none is placed upon the foliage of the trees. Then another tier of trees is placed on the moss, and the process continued until the crate is filled. Care must be taken not to pack the crowns too tightly or to get them wet, as either may induce heating. If the roots are packed as firmly as they should be, the tops may be too tightly together. To overcome this difficulty it is sometimes desirable to place moist strips of burlap among the roots next to the moss. This will enlarge the space that they would naturally occupy and serve to keep the crowns

farther apart. When the crate is filled, moss should be placed upon and damp burlap stretched over the roots of the top tier, and the top of the crate nailed on. When ready for shipment, the trees should be packed solidly enough so that they will not jar or shake around. If they are to undergo especially trying conditions while en route, each separate bundle may be bound in damp moss and this wrapped with a layer of damp burlap. Trees packed in ways very similar to this have been shipped from California to Hawaii, and have been on the road for a month, yet arrived at their destination in perfect condition. Packing should be intrusted only to careful and conscientious men who can be supervised or who have had previous experience. Cured moss is very likely to heat when packed closely and thus burn the roots of the planting stock and kill or seriously injure it.

PACKING CRATES.

The general type of packing box in use at Forest Service nurseries has a solid bottom and ends of seven-eighths-inch material and sides and top of three-eighth-inch slatting. At the Fort Bayard Nursery both ends and sides are made of lath slatting. At the Monument and Bessey Nurseries the lath slatting formerly used on high shade frames is used in one continuous strip for bottom, sides, and top of the crates. In assembling crates, it has been found at the Pilgrim Creek Nursery that cement-covered box nails hold better than others. The essential point about packing crates is that they be cheap, light, strong, easily assembled, well ventilated, and of a size suitable for packing on a horse, which means that when filled they should not weigh over 75 or 100 pounds.

For local shipments the Monument Nursery has adopted woven wire, cylindrical crates of two sizes, one 2 feet 6 inches in diameter by 1 foot 6 inches deep and another 2 feet in diameter by 2 feet deep (Pl. II). One end of the cylinder is removable to permit packing. The stock is packed with the tops to the outside and the roots to the center around a strong iron rod which runs longitudinally up through the center of the crate. When filled, the top is put on and clamped in place by means of a washer and nut on the end of the rod as it projects through the top. This crate has some advantages over wooden ones. It is exceedingly strong, the trees can be packed more rapidly, in better shape, with less moss, and much more cheaply than with the other style of crate, and ventilation of the tops is about perfect. On the other hand, those in use cost $7 each and are very heavy, which makes the cost of shipping and their return high; and they require considerable space for storage.

Packing boxes of spruce 24 inches long by 14 inches wide by 15 inches deep cost the Wind River Nursery 29 cents each knocked down, and about 5 cents each to assemble at the nursery. Boxes of this size fit nicely into an ordinary wagon box, weigh approximately 75 pounds when filled, and are a convenient size for packing on a horse.

At the Cottonwood Nursery boxes or crates 12 inches by 14 inches by 2½ or 3 feet are used. The 3-foot size will hold 20,000 2–0 Douglas fir, 7,500 2–1 Douglas fir, 10,000 1–0 yellow pine, or 6,250 1–1 yellow pine; the 2-foot size will hold 20 per cent less. A 16 by 16 by 24 inch crate at the Pilgrim Creek Nursery holds 800 1–2 western yellow pine, 1,000 1–1 bigtree, 1,250 1–1 western yellow pine, or 1,500 1–2 sugar pine or 1–1 incense cedar.

At the Savenac Nursery the trees are rolled in a strip of burlap for shipping. The device for making the rolls is somewhat on the order of a shingle-weaving machine. Two 6-foot lengths of lath yarn fastened by means of poultry netting staples to two wooden cleats (the cleats 18 inches apart and the two lengths of lath yarn 12 inches apart) 2 feet long are first placed in the bottom of the packer. A strip of burlap 6 feet long and 21 inches wide is placed over the lath yarn and cleats, and over the burlap is laid a 6-foot sheet of 18-inch "butcher's" wrapping paper. The bunches of trees, after being moderately root pruned, are then laid in the packer in two tiers, roots to the center, each layer being well packed in wet shingle tow. When the container is full, the ends of paper and burlap are drawn together at the top and the ends of the burlap are wrapped around a good hard strip of wood (tamarack 1 inch by 2 inches by 2 feet). The ends of this stick extends about 2 inches beyond the edges of the burlap. On these uncovered ends a grip is secured by means of a long tool—16 inches—similar to a wagon hammer. With this purchase the burlap can be twisted as tight as its tearing resistance will permit. When the burlap has been drawn tight this wrenching tool is held in position by means of a catch on the packer and the hands are free to tie the bundle with the lath yarn. This completes the operation. The front side of the packer is let down and the bundle taken out (Pls. XXI and XXII). The burlap strips are saved in the field and at the close of the season shipped back to the nursery.

Aside from a considerable lowering of the cost, a number of other advantages are claimed for this method; the number of trees per bundle can be varied; one man can pack approximately one-half million trees per day; the bundles are easy to handle; they will not break when thrown around; and they make a better pack for pack horses.

In these bundles the trees stand transportation well and they do not heat or dry out readily. Packed in this manner, they have been left in a warm place for 6 days and were cool and moist when the bundle was opened.

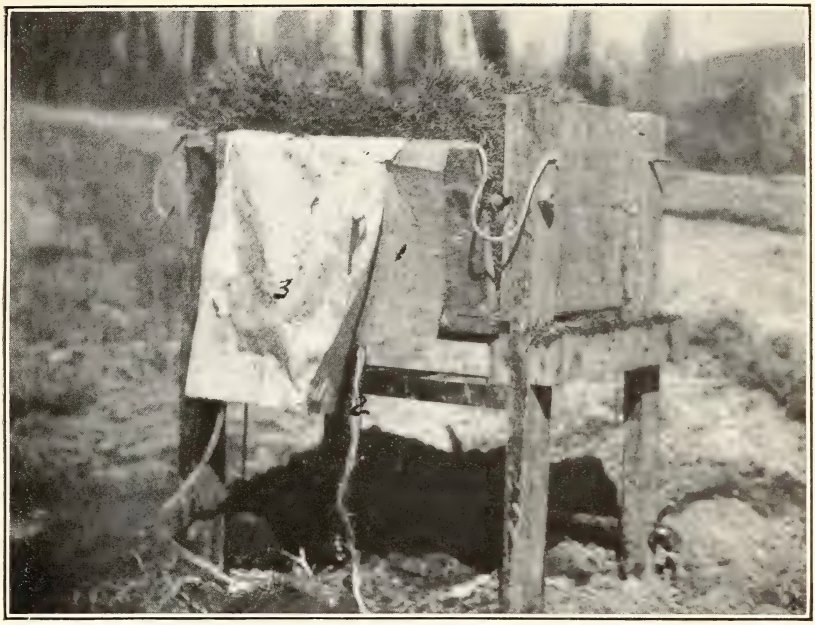
SHIPPING.

Because of the danger which accompanies delays en route of growth starting, of drying out, of heating, or of holding up planting operations, shipments of nursery stock should preferably be by express; or, if the packages are small, by mail. Shipments by freight are much cheaper, and for distances up to 300 miles have proved very satisfactory in California. Special arrangements can sometimes be made with freight agents to put a shipment through promptly, but the risk is greater than with express shipments. Shipments are liable to be delayed under the best of conditions, because express or railroad officers do not always realize the necessity of prompt delivery. To avoid this, it is believed best for the shipper to indicate plainly on the outside of each crate that the contents are "perishable," that they contain "live plants" the "prompt delivery" of which is "necessary," or some similar phrase. Night shipments are preferable to day shipments.

DISEASES AND INJURIES IN NURSERY.

DAMPING-OFF.

Damping-off is a source of great danger to young seedlings. This disease is most commonly caused by one of three fungi, *Pythium bebaryanum* Hesse, *Rhizoctonia* sp., and *Fusarium* sp., and its presence in a bed is indicated in a very characteristic manner. The stems of seedlings attacked exhibit a rather dirty, watery, or rotten appearance at the surface of the ground and for a quarter of an inch or more upward. The stems become flaccid and limp in this section, and the seedlings topple over unless they are held up by surrounding plants. There is no recovery. Seedlings are most susceptible to danger from this source during a period of from 2 to 6 weeks following germination, and some species are more susceptible than others. The seedling may even be attacked before it appears above the ground.



F–26332A

FIG. 1.—TREES IN PLACE READY FOR BINDING.

F–26333A

FIG. 2.—BUNDLE TIGHTENED AND READY FOR TYING.

F-28326A

FIG. 1.—TYPE OF PACKING CRATE IN USE AT WIND RIVER NURSERY.

Fifty thousand western white pine packed for shipment, Savenac Nursery.

F-9-CRT

FIG. 2.—TYPES OF SHIPPING CRATES USED AT MONUMENT NURSERY—WOODEN FOR SHIPPING LONG DISTANCES, WIRE FOR SHORT DISTANCES.

Susceptibility of species to damping-off in Forest Service nurseries.

Nursery.	Species.	
	Most susceptible.	Least susceptible.
Savenac	Pinus ponderosa [1] Pinus strobus [1] Pinus monticola [1]	Pseudotsuga taxifolia. Larix occidentalis. Picea engelmanni.
Boulder [2]	Pinus sylvestris Pseudotsuga taxifolia Pinus ponderosa	Pinus austriaca.
Trapper Creek	Pinus monticola	Pinus ponderosa.[3]
Monument	Pinus austriaca Pinus ponderosa	Pseudotsuga taxifolia. Picea engelmanni.
Bessey	Pinus resinosa Pinus divaricata	Pinus austriaca. Pinus sylvestris. Pinus ponderosa.
Fort Bayard	Pinus attenuata Pinus sylvestris	Pinus ponderosa. Pinus jeffreyi. Juniperus monosperma.[4] Juniperus pachyphlœa.[4] Cupressus arizonica.[4] Pinus edulis.[4]
Cottonwood	Picea engelmanni Pseudotsuga taxifolia [1]	Pinus monticola.[4] Pinus ponderosa.[4] Pinus contorta.[4]
Beaver Creek		Pinus ponderosa.[4] Pinus contorta.
Pocatello	Pseudotsuga taxifolia	Pinus sylv[illegible] [1] Pinus austi Pinus ponder[illegible]a.[1]
Pilgrim Creek	Pseudotsuga taxifolia [1] Sequoia washingtoniana [1] Pinus jeffreyi.[1] Pinus sylvestris.[1]	Pinus ponderosa.[4] Libocedrus decurrens.[4]
Converse Flats	Pinus ponderosa [1] Pinus jeffreyi [1]	Libocedrus decurrens.[1] Cedrus deodara.[1]
Wind River	Pseudotsuga taxifolia [1] Larix occidentalis [1]	Pinus monticola.[1] Pinus ponderosa.[1] Abies nobilis.[1]
Page Creek	Pinus lambertiana	Pseudotsuga taxifolia.[1] Pinus ponderosa.[1] Chamæcyparis lawsonia.[1]

[1] Damping-off not serious.
[2] Attack not serious except with fall-sown western yellow pine and Douglas fir.
[3] Worse in fall-sown than in spring-sown beds.
[4] Not affected by damping-off.

At nearly all Forest Service nurseries damping-off has not been particularly virulent, whether because of properties of the soil or not is unknown. When it has appeared, the most general method practiced for its control has been simply to expose the beds to full sunlight and, where practicable, to stir the surface soil. The spread of the fungi is promoted by damp, warm soil and weather, although *Rhizoctonia* and *Pythium* attack seedlings even in rather cool, damp weather. The effect both of exposing the soil to the sun's rays and of stirring or cultivating it is to dry it out and thus produce a condition unfavorable to the further development and spread of the fungi.

An effective method of control has been worked out by Hartley [1] and Pierce at a number of nurseries. At the Bessey Nursery, where damping-off has at times been very serious, commercial sulphuric acid is applied to the beds immediately after the seeds are

[1] Hartley, Carl, and Pierce, Ray G. "Control of Damping-off of Coniferous Seedlings." U. S. D. A. Bul. No. 453.

sown and covered at the rate of three-sixteenths of a fluid ounce in solution with 1 quart of water to the square foot of seed-bed surface. This acid applied at the rate designated has been found very efficient. When acid is used seed beds must be kept well moistened during the germination period. Neglect of this results in concentration of the acid in the surface soil through capillary rise of the solution, and the growing apex of the radicles of the germinating seed are killed, which may result in the death of the plants. For some other nurseries different amounts of acid were found successful; at a good many places it was found unnecessary to take any special precautions in the way of extra watering in the acid-treated beds. The results obtained from this treatment are in accord with what has been found true elsewhere, that damping-off is much less prevalent in soils of an acid than in those of a weakly alkaline reaction. Experiments at the Vermont Agricultural Experiment Station[1] indicate that damping-off is likely to be less serious in beds to which there has been applied a well-rotted compost of horse manure and muck. Such an application will undoubtedly tend to make the soil more acidic in its nature and thus antagonistic to the development of the fungus.

In addition to checking damping-off effectively, acid treatment at the Bessey Nursery has resulted in the production of stock that averages fully an inch higher than nonacid-treated stock. At this nursery another feature of the acid treatment is that it seems to kill the weed seed and very greatly reduces the cost of weeding thereby. During 1912 the cost of weeding acid beds was $0.0044, while the cost of nontreated beds was $0.0125 per square foot.[2] The extra cost of acid treatment was $0.005 per square foot. The total cost of acid and weeding was therefore $0.0094 per square foot, as compared to $0.0125 for weeding only of nontreated beds. Thus the saving in the cost of weeding at least fully offsets the increase in cost due to acid treatment.

A 1 per cent formaldehyde solution applied at the rate of three-fourths of a gallon per square foot about a week before the seed is sown has been shown[1] to be very effective in preventing damping-off, but it is known that formaldehyde may kill seed which is still dormant. On the whole, the experience with formaldehyde at most Forest Service nurseries has not been as satisfactory as with acid. The formaldehyde, especially with sandy soils, must be applied two or three weeks before seed are sown in order to avoid killing them.

[1] Gifford, C. M. "The Damping-off of Coniferous Seedlings." Vt. Agr. Exp. Sta. Bul. 157.

[2] Cost of acid treatment will be temporarily higher during the European war on account of increased price of acid.

However, it has the advantage of never making necessary special watering after the seed are sown.

At the Monument Nursery hot dry soil sprinkled over and worked into the soil of an affected area has proved quite effective in checking damping-off.

Sowing at certain seasons as a preventive of damping-off is indicated by the experience of some nurseries. Western yellow pine and Douglas fir at the Boulder, western yellow pine at the Savenac, and Douglas fir at the Wind River suffer the most severe losses, and jack pine at the Bessey Nursery suffers least, when the sowing is done in the fall.

WINTER MOLDING.

A type of injury which has proved serious only at the Cottonwood Nursery is due to molding. Molding is caused by heavy accumulations of snowfall remaining on the nursery area longer in the spring than normal. When the snow goes off the plants are found pressed down flat upon the ground, with foliage brown or black and moldy. In some cases the stems remain green and the plants recover, but usually the plants succumb entirely. Norway, Engelmann, and blue spruce have never suffered very heavily, particularly after the stock has passed its first year. Douglas fir is the worst affected species and suffers most in 1–0 and 2–0 stock. Western yellow pine has never been much affected as seedling stock, but losses have occurred in the 1–2 transplant beds. No effective preventive is known for this at present. Douglas fir suffers less severely in drill-sown than in broadcast-sown seed beds.

WIND INJURY.

Wind may whip, break, and dry up plants, or in loose soils drift the soil over them. Windbreaks of some bushy shrub or tree or of artificial construction are the most efficient remedy.

SUMMER DROUGHT INJURY.

Summer drought injury[1] is a physiological trouble rather than one due to fungi. It is caused by an insufficient amount of water or shade; is evidenced by the dying of the roots, a yellowing or browning of the tops, and the final death of the plants and is most usual during the hot, dry months of summer. It has often been called simply blight and, until recent investigations by Mr. Hartley, was thought to be due to fungi. Summer drought injury has caused considerable damage at the Bessey Nursery and is more likely to be a source of danger at a nursery where the soil is loose and subject to very rapid drying

[1] For full discussion, see Bulletin of the United States Department of Agriculture No. 44, "The Blight of Coniferous Nursery Stock," by Carl Hartley, of the Bureau of Plant Industry.

out than at one with a heavier, more retentive soil. It is also likely to be more serious with shade and moisture loving species, such as spruce and western red cedar, than with such drought-resistant species as western yellow pine. As the absorbing portions of the roots die at the same time or even just preceding the time of yellowing of the leaves, it is important that the trees never be allowed to reach this stage. Recovery is then doubtful. The remedy is obvious. Excessive crowding in seed or transplant beds should be avoided; the soil should be kept fresh at all times after the damping-off period has passed; exceptionally heavy watering should be practiced during periods of particularly drying or hot weather; and shade should be supplied if necessary.

A type of injury similar to summer drought injury but rather uncommon may be caused by an excess of water. This makes itself evident by the yellowing and final death of the plants. Recovery from this is claimed to be slower and even more doubtful than from sun scorch.

WINTERKILLING.[1]

Winterkilling produces a condition in plants very similar to that of sun scorch and physiologically is due to the same cause; that is, the inability of the roots to furnish moisture to the tops as fast as it is lost by transpiration during periods of severe, trying weather. Winterkilling differs from sun scorch, however, in that it occurs during the winter, and it is not necessarily due to insufficient water in the soil but rather to the fact that the water is frozen and thus not available to the plant. Periods of strong winds or of bright, warm days during the winter when the ground is frozen are most likely to cause winterkilling. Sometimes only a portion of the top of the plants is injured. This is especially likely to occur with any portion which protrudes above a snow covering. Mulching is the preventive for this type of injury.

FROSTS.

Losses from killing frosts are infrequent but usually extensive when they do take place. This is due to the relatively few species growing in any one nursery and the large number of plants which happen to be in the same class and in a like susceptible condition. If seed is obtained in localities which have a climate similar to that of the nurseries, if it is sown so as to give the trees the benefit of the full growing season, and if growth is not stimulated too late in summer through watering and cultivating, no further measures are required to prevent frost-killing under normal conditions. But additional

[1] For full discussion, see Bulletin of the United States Department of Agriculture No. 44, "The Blight of Coniferous Nursery Stock," by Carl Hartley, of the Bureau of Plant Industry.

safeguards are necessary to prevent losses resulting from unusual conditions.

In cases where the slope of the ground permits and where a supply of water is available, heavy flooding of the beds will prevent frost damage. The temperature of the water is usually above that of the air and it does not cool so rapidly. A considerable quantity of wild meadow hay spread over the beds will prevent frost injury as well as rapid thawing in case freezing has already taken place. The method followed in orchards of building a smudge may be used. Either wood or hay will serve the purpose, and small piles will have to be distributed in the paths throughout the nursery. Emphasis must be laid upon the need of anticipating the danger, of preparing for it, and taking action when the danger is most imminent. Heavy frosts can generally be foreseen the evening before and the local Weather Bureau can doubtless notify the man in charge when there is any real danger. Thermostat alarms may also be provided. If proper precautions are taken, wholesale losses can be prevented even though the plants are tender and the frost heavy. Losses from frost have not in general been heavy at Forest Service nurseries. At the Savenac Nursery 1–0 western yellow pine, Douglas fir, and Engelmann spruce; at the Monument, Douglas fir and Engelmann spruce; at the Pocatello, 1–0 western yellow pine not under shade frames; at the Wasatch, 2–0 Douglas fir; and at the Boulder, 1–0 Douglas fir have been injured to some extent; while at the Wind River spring-sown seedlings of noble fir were badly injured by a late frost. At the Beaver Creek Nursery mulching with ripe timothy hay effectually prevented frost damage, but resulted in the production of a heavy crop of hay, which vastly increased the amount of weeding necessary in the nursery.

INSECTS.

The principal insect damage which has been noted in the nurseries of the National Forests thus far has been due to cutworms, white grubs, grasshoppers, aphids, and pine-tip moths. The following information regarding life histories and habits of these insects and the general methods of combating them has been furnished by the Bureau of Entomology, which investigates insects affecting forest and shade trees and hardy shrubs, including forest nurseries.

CUTWORMS.[1]

Cutworms are the larvæ or caterpillars of night-flying moths and sometimes are destructive to young seedlings, cutting them off at or

[1] For further information on cutworms and their control, see U. S. Dept. Agr. Farmers' Bulletin 739.

near the surface of the soil. They feed at night, concealing themselves in the soil or under rubbish during the day. Scratching the soil about an injured plant to a depth of one or possibly two inches usually reveals the worms, and this method of hand destruction of the larvæ may be practiced in small areas where the infestation is scattering.

Cutworms may be destroyed also by means of a poisoned bait prepared and applied as follows: Mix 50 pounds of bran with 4 pounds of lead arsenate and 2 gallons of low-grade molasses until the mass is made into a stiff dough. The chopped oranges or lemons mentioned in the bulletin referred to (see footnote) are not always essential, but the molasses is absolutely so. In semiarid regions it is advisable to add water to prevent rapid desiccation and to distribute the bait toward evening. About a tablespoonful of the bait should be placed every foot or two along the nursery row. In case of migration from an adjoining field, the nursery may be protected by running a narrow band of the poisoned bait entirely around the edge or along the side nearest the source of infestation. A ditch constructed around the Savenac Nursery proved somewhat effective in trapping some of these larvæ which were migrating from an adjacent clover field.

WHITE GRUBS.[1]

White grubs, the larvæ or young of beetles commonly known as May beetles or "June bugs," are often a serious menace to nursery stock, especially conifers, injuring or killing the seedlings and transplants by cutting off the smaller and girdling the larger roots. Most of the May beetles have a three-year life cycle, and except the one or two months (usually May and June) during which the beetles appear above ground to mate and feed, this entire period is spent underground, and two years of the three are spent in the grub stage. In the extreme northern limits of the United States, that is, in northern Wisconsin and Minnesota, where the grubs are important enemies of conifer seedlings and transplants, this insect has a four-year cycle, due to the shorter seasons. The grubs occur at various depths in the soil, and their proximity to the surface is largely dependent on the temperature and moisture conditions. They are found deeper during the winter months and more often quite near the surface in early fall. Plowing or cultivating the soil at this time, therefore, is of value, especially if done the year following the most severe summer injury, which would be the season the insects are transforming from grubs to beetles, at which time disturbances

[1] For further information on these insects, see U. S. Dept. Agr. Farmers' Bulletin 543.

are usually fatal to them. The value of plowing or cultivating a field is greatly enhanced if poultry have the run of the field and are encouraged to forage during these periods. Each locality usually has one brood predominating, and the history of the brood should be learned, thus permitting the practices of persistent hand collecting of the grubs and beetles, spraying trees whose foliage is favorite food of the beetles with an arsenical during the flight of the beetles, and careful tilling of the land to prevent grass and weeds from making a growth during such flight, all of which are helpful expedients.

GRASSHOPPERS.[1]

Grasshoppers are often a serious menace in nurseries, and have been so at the old Garden City and the Page Creek Nurseries. The best poison remedies recommended against these insects are the poisoned-bran bait, described above, and the modified Criddle mixture. The latter is prepared as follows: Fresh horse droppings, one-half barrel; lead arsenate, 2 pounds; finely chopped oranges or lemons, 6 to 8 fruits, all thoroughly mixed. For protection against these insects the bait is best distributed broadcast over the nursery, and especially around the outer borders or open side, as circumstances may dictate. Fine screens around the seed beds and a brood of chickens at Trapper Creek have proved more effective than anything else tried.

APHIDS.

Under certain climatic conditions aphids are apt to appear in greater or lesser numbers and do a corresponding amount of damage. These insects feed by sucking the sap of the plants, thus checking their growth and lowering their vitality. A woolly aphid has seriously damaged Jeffrey, western yellow, and Austrian pines at the Converse Flats Nursery, and was worse on the first-named species. Kerosene emulsion is one of the standard remedies and is especially effective if applied early in the spring, before the insects have multiplied excessively and the woolly species have covered themselves.

Kerosene emulsion is prepared as follows: Take 2 gallons of kerosene, one-half pound of laundry or fish-oil soap, and 1 gallon of water; dissolve the soap in hot water, remove the solution from the fire, promptly add the kerosene, and agitate the mixture vigorously for about 5 minutes until it becomes creamy—an emulsion. A most effective way of agitating the mixture is to pump it back

[1] For further information on the habits of these insects and methods of control, see U. S. Dept. Agr. Farmers' Bulletin 747.

into the original container for several minutes. To avoid boiling, a naphtha soap may be used, but the quantity of soap must be doubled and the water must be soft (rain water). This is the stock solution and it must be diluted with water before using, thus: To each 2 gallons of water add 1 gallon of the emulsion in the fall, and one-third of a gallon of emulsion in the spring. The size of the spraying apparatus will have to be determined by the size of the nursery. In most of them a knapsack sprayer will probably be most satisfactory. Using potash soaps and warm solutions, well strained, will prevent clogging of nozzles.

The other standard aphid remedy is 40 per cent nicotine sulphate, 1 part in 1,000 to 2,000 parts of water, with fish-oil or laundry soap added at the rate of 1 pound for each 50 gallons of the spray mixture.

PINE-TIP MOTH.

A pine-tip moth has been injuring the western yellow pine at the Bessey Nursery, Nebraska, since 1909. The small larvæ effectually kill the succulent growing tips of these trees by boring into them. On account of the extensive distribution of the insect in the plantations adjoining the nursery, no effective practical remedy has as yet been worked out.

BIRDS.

Mourning doves, juncos, the Canada jay, the blue jay, the redpolled linnet, and the black-headed grosbeak do some damage at the Forest Service nurseries by scratching up the seed or nipping off the tops of newly sprouted seedlings to which the seed coat is still attached. They are held in check either by poisoning with grain prepared in the same way as for mice or by shooting.

RODENTS.

Rodents damage plants in a number of ways: By destroying seed in the seed beds, by digging in the nursery, by covering up plants, by girdling the stems, and by eating the tops, particularly during the winter. The white-footed mice, chipmunks, ground squirrels, gophers, and moles are the chief offenders. Against the first three and to some extent against birds several cats have been found to afford very good protection. Poisoning is also practiced. To be effective against mice and chipmunks the poison should be thoroughly distributed over the area immediately surrounding the nursery, under old logs, brush piles, outbuildings, rock piles, or any other likely retreat for these animals. Poisoning is most effective during spring or early summer before the natural food of these ani-

mals (seed and berries) ripens. Where mice work under a mulch and girdle nursery stock during the winter, the scattering of waterproof poisoned wheat throughout and under the mulch has been found effective in destroying them at the Monument Nursery. This bait is prepared as follows, in accordance with Circular 78 of the Biological Survey:

Wheat	1 bushel.
Tallow	1 quart.
Saccharine[1]	2 teaspoonfuls.
Strychnia (pulverized)	2 ounces.

The wheat should be slightly warmed, the saccharine and strychnia added, and the whole stirred thoroughly, and then the melted tallow applied.

Mice and chipmunks are also destroyed by sinking large cans to the level of the ground, partly filling them with water, and distributing seed on its surface. In attempting to secure the seed the rodents fall into the water and are drowned. About 700 were destroyed in this manner at the Pocatello Nursery in one season. Small baited spring traps placed near or upon the seed beds are quite effective in destroying mice.

At the old Garden City Nursery poisoned corn proved effective against kangaroo rats. At the Fort Bayard and the Pilgrim Creek Nurseries gophers are successfully combated by the use of gopher traps. At the Pilgrim Creek Nursery moles are effectively controlled by trapping. Carbide fumes were tried for driving out moles at the Page Creek Nursery, but were not effective. At the Converse Flats Nursery potato parings at the rate of one-half bushel to 1 ounce of strychnia (alkaloid) and 1 teaspoonful of saccharine are used to destroy digger squirrels. The parings are distributed in the burrows of these animals. At this nursery poisoned cracklings are found effective against chipmunks. This is prepared in accordance with the formula in Circular 82 of the Biological Survey, as follows:

Coarse crackling meal	¾ quart.
Strychnine (alkaloid)	30 grams (1/16 ounce).

Chop lard cracklings (fried down suet) to coarse meal (containing chunks one-fourth to one-half inch square). Slowly sprinkle with the powdered strychnine and mix constantly to distribute it evenly. Add one-fourth quart of fine crackling meal and mix well to cover the strychnine and disguise its bitter taste.

For some of the latest methods developed for combating rodents the Forest Service is indebted to Mr. S. E. Piper, of the Biological Survey. These are as follows:

Mix 1 heaping tablespoonful of gloss starch in one-half teacup of cold water and stir with 1 pint of boiling water to make a thin, clear mucilage. Remove

[1] Saccharine is not essential.

from the stove. Mix together 1 ounce of powdered strychnine (alkaloid)[1] and 1 ounce of powdered bicarbonate of soda and stir with the starch to a smooth, creamy mass. Stir in 1 tablespoonful of glycerine and finally one-eighth ounce of saccharine. Apply to 20 quarts of good, clean oats or wheat and mix thoroughly to coat each kernel.

This poison is effective in destroying chipmunks, kangaroo rats, pocket mice, the smaller species of ground squirrels, and at times kills white-footed mice.

Oats are generally the most successful bait. On account of the skill of chipmunks in "hulling," wheat is more effective for these animals. Barley, in the proportion of 16 quarts to each ounce of strychnine, has given best results in destroying the larger "digger" ground squirrels and is most effective during the dry summer season.

There is another process of applying the poison which is an improvement over that just described, in that it delays the taste of strychnine, the intense bitterness of which is the greatest factor detracting from success in poisoning certain rodents. This poison has been used with great effect against rodents which have hitherto exhibited marked aversion to strychnine baits. The fact that the poison coating readily separates from the bait is also of importance to the success of this preparation, especially for such rodents as habitually "hull" grain. In the process of hulling sufficient strychnine to kill flakes off in the animals' mouths. Grain poisoned in this way must be handled carefully to avoid loosening or grinding off the poison coating. It should be freshly prepared in small quantities, for use each day, as follows:

Mix together one-fourth ounce of powdered strychnine alkaloid, one-fourth ounce of powdered bicarbonate of soda, a scant one-half treasoonful of saccharine, two heaping tablespoonfuls of dry powdered starch; stir with enough cold water to make a thin paste of the consistency of cream. Apply gradually to the material to be used as bait, mixing vigorously to distribute the poison as evenly as may be and to prevent the formation of lumps.

Oats, wheat, cracked corn, and dry coarse meals of all kinds may be so poisoned. For ground squirrels, chipmunks, and medium-sized rodents generally, one-fourth ounce of strychnine is sufficient for 4 quarts of bait; but for white-footed mice the amount of bait may be doubled. Among baits especially attractive to the latter animals may be mentioned pine seeds (both whole and crushed seeds worth trial), roasted peanuts crushed to a coarse meal, crushed wheat, and mixtures of crushed or chopped grains.

Poisoned baits of sweet potato almost invariably kill pocket gophers if placed in the underground runs without too much disturbance of the latter. Baits of carrot or parsnip may be substituted, or corn, poisoned as in the first formula described, but none of these are so completely successful as sweet potatoes.

The baits of vegetables should be cut about 1 inch long and one-half inch square and washed and drained. From a pepperbox slowly sift one-eighth ounce of powdered strychnine (alkaloid) and one-tenth of this quantity of saccharine (ground together in a mortar) over about 4 quarts of the dampened baits, stirring to distribute the poison evenly.

The runways, which are usually 4 to 8 inches beneath the surface, can be located by means of a probe made of any strong handle an inch in diameter and 36 inches long. One end should be bluntly pointed. Into the other should be fitted a piece of three-eighths inch iron rod, protruding about 12 inches and

[1] If strychnine sulphate is used, dissolve in the boiling water before adding the starch; also dissolve the bicarbonate of soda before adding to the poisoned starch. Care is necessary that the resulting mixture does not greatly exceed a pint.

bluntly pointed. A foot rest aids in probing hard soils. By forcing down this iron rod near gopher workings or a foot or two back of fresh mounds the open tunnel can be felt as the point breaks into it. The blunt end of the instrument is now carefully used to enlarge the hole, a bait or two is dropped into the run, and the probe hole closed.

Baits need to be placed at only two points in each separate system or group of 10 to 30 mounds, which is usually the home of a single gopher. In our experience baits placed in open underground runs have invariably killed the gophers. The method has found great favor wherever it has been introduced.

At the Converse Nursery, in California, wood rats, or "pack" rats (*Neotoma*), have been found responsible for a considerable part of the damage to transplants usually ascribed to rabbits.

Wood rats eat little or nothing of the trees they cut, but carry the green tips into their nests to store away. These animals are rarely killed by any of the baits which have been described, though they pack away such baits readily enough. Effective results have been obtained by dusting baits liberally with finely powdered strychnine, as the rats are killed in packing them. Dry oatmeal biscuits one-half inch square and one-fourth inch thick, cut from a stiff dough of oatmeal and water, after rolling it in sheets, have proved to be especially successful baits. Raisins and whole corn may also be used.

Though both cottontails and jack rabbits fall victims to poisoned oats during periods when their natural food is scarce, this poison can not always be relied upon to destroy them when it is most important to check their depredations. Green or ripening grain heads of barley or wheat are among the most attractive baits in summer. Soaked for 48 hours or more in a solution of 1 ounce of strychnine sulphate and one-eighth ounce of saccharine in 2 gallons of water, such baits have occasionally proved very successful. They should be used only in locations where live stock is not endangered.

FERTILIZERS.[1]

The character of soil preferable for a nursery has been described, but such soils are not always to be found. Continuous raising of crops of trees, moreover, will eventually deplete even the best soils of the chemical constituents most essential for plant growth. It will also impair their physical qualities. Improvement of the soil by fertilization will accordingly be necessary. According to investigations by von Schroeder,[2] the average quantity of nitrogen, potassium, and phosphoric acid (the three most essential plant foods) needed in one year by 1 to 3 year old spruce is about equal to the amount absorbed from the soil by a crop of corn, potatoes, or meadow hay. The physical and chemical qualities of a soil may be improved through the addition of manure, leaf mold, compost, or marl, and chemical fertilizers. Some of the chemical fertilizers, however, rapidly pass into solution and have no appreciable effect upon the physical quality of the soil.

[1] The information cited in regard to fertilizers is taken, but not wholly verbatim, from "Die Pflanzenzucht Im Walde," by Dr. Herman von Furst, and represents the views of German nurserymen.

[2] "Tharandter Forstliches Jarbuch," 1893–94.

Two classes of fertilizers may be distinguished: "Complete" fertilizers, which contain all the important elements necessary for plant growth, and "incomplete" fertilizers, which furnish only one or more of these elements.

COMPLETE FERTILIZERS.

Stall manure, consisting of the animal excrement and the litter on which it is found, is a very effective fertilizer, not only because it contains the most essential plant foods—nitrogen, potassium, and phosphoric acid—but because it improves the physical qualities of the soil and by numerous microorganisms increases its activity and fermentation. Sheep and horse manure are richest and decompose rapidly. Cattle manure decomposes less rapidly. The former is best for application to compact, the latter to loose soil. As manure is not usually to be had in sufficient quantities at a nursery and is often difficult and expensive to obtain, it is frequently used in compost.

Where humus can be obtained it has been found to be excellent, both as a fertilizer and for its effect in improving the physical quality of the soil.

The value of compost as a fertilizer is decided by the material entering into it and the treatment given compost heaps. Organic substances of every kind may be used for this—weeds, raw humus, turf, and even street sweepings. To this material is added quicklime for more rapid decomposition and horse manure in layers. Ashes may also be used to strengthen it. Weeds hoed from the nursery may be used alone for compost. In such cases it is necessary to mix them in thin layers with quicklime, allow the heaps to remain untouched for some time, and then stir repeatedly. When thoroughly decomposed it is ready for use.

One of the German head foresters gives the following formula for making good compost: The first layer, about $\frac{1}{2}$ inch thick of organic substances, grass, heather, weeds, sawdust, etc., is sprinkled with a thin layer of unslaked lime, then another layer of grass and weeds is added, then a layer of lime, etc. In this manner it is heaped up like charcoal but shaped broader and lower so as to catch the rain, and then covered on all sides with carefully crushed earth. The slaking of the lime begins after a few days and in from 2 to 4 days later is completed. During this time the heaps should be examined twice a day and all crevices in the earth covering closed in order to keep the heat, steam, and ammonia from escaping. After from 4 to 6 weeks the material is ready for use.

INCOMPLETE FERTILIZERS.

WOOD ASHES.

With the exception of nitrogen, which is lost during the process of burning, wood ashes contain all the nourishing substances, potash, lime, phosphoric acid, magnesia, and sulphuric acid, in a form capable of absorption. Wood ashes may accordingly be added to the list of fertilizers for general use. The quantity of these elements, particularly phosphoric acid and potash, contained in the ashes varies with the species, the ash of hardwoods being much richer in such material than that of conifers. In sandy soil care must be taken in using wood ashes, because such soil is not capable of much absorption. The use of such a strong fertilizer has an unfavorable effect, because it furnishes the roots with too much carbonate of potash, which acts as an alkali; on the other hand, its use on clayey humic soil is very favorable. Pure wood ashes, however, are seldom used but are generally mixed with compost; their use deserves all the more consideration, as they can usually be obtained at little expense by burning the brush around the nursery or by utilizing the wood ashes from the stoves of the nursery buildings.

NITROGEN FERTILIZERS.

Nitrate of soda $NaNO_3$ (Chili saltpeter) contains 15 or 16 per cent of nitrogen, is easily dissolved by water, and quickly distributed. It has a quick and decisive effect, but the portion not absorbed at once by the plants quickly sinks to the subsoil and may be lost. Its best use is for intermediate fertilizing—that is, the fertilization of beds in which after the growing season has started the plants appear unhealthy and the cause is apparently due to lack of nitrogen.

A somewhat better commercial nitrogen fertilizer for forest tree nurseries is ammonium sulphate $(NH_4)_2SO_4$, obtained from the refuse in gas manufactories where the ammonia produced is fixed by sulphuric acid; the white salts contain about 21 per cent of nitrogen, which is only effective after being changed into nitrates. A simultaneous fertilization with lime or carbonate of lime should be avoided, as in such a case by decomposition of the salts the ammonia becomes ineffective and evaporates.

Blood powder or blood guano, made from the blood of slaughtered animals mixed with powdered lime, contains from 10 to 12 per cent of nitrogen and from 1 to 2 per cent of phosphoric acid. Horn powder made from the refuse of horns, hoofs, and hair, ground and

dampened, contains from 10 to 12 per cent of nitrogen and from 5 to 6 per cent of phosphoric acid. Both of these substances act rapidly.

POTASH FERTILIZERS.

For the introduction of potash two salts, kainite and carnallite are good. These salts contain sulphuric acid and magnesia in addition to potash. Their use, especially that of the kainite, must be watched carefully, as the chloride easily corrodes the plants, so that too great a quantity should be avoided, especially directly before sowing or transplanting. Disregard of such precautions may lead to the total destruction of the plants. The most practical method is to mix the kainite in the compost heaps with the addition of lime, thus neutralizing the effects of any chlorine that may be liberated.

PHOSPHORIC ACID FERTILIZERS.

Bone meal and Thomas meal, also known as Thomas slag or basic slag, may be used to supply the soil with phosphoric acid. Crude dry bone meal contains from 20 to 22 per cent phosphoric acid and from 4 to 5 per cent nitrogen. Thomas meal, a by-product in the manufacture of steel, which is more generally used in European nurseries, contains from 11 to 23 per cent of phosphoric acid and from 38 to 39 per cent of lime, besides iron, manganese, silicic acid, and magnesia. Possible damage may arise from the use of Thomas meal if it is applied just previous to planting the beds.

LIME FERTILIZERS.

Lime is not only an important plant substance found in all plant ashes, but it has an important influence on the soil; it hastens the disintegration as well as the decomposition of the organic substances, neutralizes the free acids which may be injurious to the plants, such as humic and phosphoric, and makes the soil loose and friable. Some of the other fertilizers mentioned, bone dust and Thomas meal, contain lime, but with soil very deficient in lime a heavier addition may be necessary. For this purpose burnt lime, carbonate of lime, or marl may be used.

The burnt or unslaked lime is the most effective form. It contains from 90 to 95 per cent of lime and is generally used as part of a compost. It may also be placed directly on the ground in small heaps and then slaked by pouring over it one-third its weight in water and covering with a layer of earth 3 or 4 inches thick. In 24 hours it will change to a fine powder and should then be spread around and worked into the soil.

The carbonate of lime is a natural product and is simply applied in a pulverized state. When mixed with sand and clay it forms marl,

a substance which is often found naturally in large beds and which can be applied directly as a fertilizer. It is an especially good material to add to light, sandy soil, on account of the clay contained.

GREEN FERTILIZERS.

The use of green fertilizer is the easiest and perhaps the cheapest method of supplying soils with nitrogen, and as it adds humus it improves their physical quality as well. The method consists in the raising of rapid-growing herbaceous plants and plowing them under before the stems become woody. The leguminous plants are preferred for this purpose. They have the ability, with the aid of the microorganisms in the soil to assimilate the free nitrogen of the air and store it in the root tubercles. A number of plants may be used, among which are the lupines, yellow lupine in particular, different kinds of vetch, field peas, cowpeas, beans, soy beans, dwarf beans, frijoles, and serradilla. Engler found that on all soil rich in lime field peas and cowpeas furnish the richest fertilization; on rather moist soil with little lime the yellow lupine is the most suitable; vetch is suitable only for heavy and compact soil and furnishes a cheap but not so rich a fertilizer; in high localities with rigorous climate and later sowing the field pea is recommended. Cowpeas are the most expensive, but they produce the greatest volume and, on account of their strong root development, are especially to be recommended for rough, hard soil or for soil which has long lain fallow.

Vigorous growth of leguminous plants and the assimilation by them of free nitrogen is dependent upon the presence in the soil of certain fungi which live in a symbiotic relation with the plants. When such fungi are not present—their absence is indicated by the poor growth of the plants—they must be introduced. This is accomplished by the so-called inoculation of the soil. Surface soil from other fields where legumes have grown in a flourishing manner is collected and sown over the new area at the rate of about 100 pounds per acre. The same result can also be secured by the use of inoculating fluids, with which the seed are moistened.

CHOICE OF FERTILIZERS.

If only the chemical qualities of the soil need improvement chemical fertilizers may be introduced, but if the physical qualities need improvement the addition of humus will be necessary. The chemical fertilizers necessary can best be determined by experiment. Analyses of soil are inconvenient and expensive and give only temporary results, because the contents of the soil change with each year's production of plants. It is preferable not to use fertilizers which

contain only one of the desirable elements. However, if this is necessary, it should be remembered that the growing of cover crops is the most inexpensive way of introducing nitrogen; that phosphoric acid can be introduced by the use of Thomas meal and bone meal, both of which also add lime to the soil; and that potash is most cheaply introduced by the use of kainites.

Commercial fertilizers (with the exception of those containing lime) do not improve the texture of the soil to any extent, and lime does not improve loose soils; commercial fertilizer is rather rapid in its action, making it preferable where quick effects are wanted, but is likely to be quickly lost through leaching out; it is expensive and sometimes difficult to obtain; and some of it contains only one or two of the elements essential to plant growth. Manure is also often difficult and expensive to obtain in sufficient quantities; if mixed with much litter not well decomposed it is likely to cause drying out of the beds; and it does not give such immediate results. On the other hand, it does not leach out rapidly, it improves the texture of both heavy and light soils, and it furnishes several of the elements which are essential to plant growth.

In choosing fertilizers the absorption capacity of the soil must also be considered. This is much greater in fine and clayey than in sandy soil; in the latter there is always danger of any soluble substance, such as saltpeter, being washed out. In such cases the nitrogen is best furnished by green fertilizing and stall manure, and lime by carbonate of lime instead of unslaked lime.

TIME AND METHOD OF INTRODUCING FERTILIZERS.

Inferior soil, even before the first crop is grown, should be fertilized. Fertilizer should be applied at a time when it will prove most beneficial to the plants. Stable manure which has not been well rotted should be applied the fall or winter previous to the spring planting. Such manure can be used just before sowing or planting if it is turned far enough under the soil so that it will not come in contact with the roots. Compost, bone meal, and slaked lime or carbonate of lime may be applied just previous to the sowing or planting of the beds. Thomas meal, kainite, and carnallite should be applied the previous autumn, or the last two in the spring just before sowing or transplanting, if used only in small quantities. Chili saltpeter should be scattered on the ground and worked in between the rows after the seed has sprouted, because it dissolves easily and is carried quickly into the soil by rain. The other fertilizers mentioned should be well mixed with the soil which makes up the root zone. It is better not to fertilize too deeply in order to encourage lateral development of the roots rather than develop-

ment in depth. The application of too great a quantity of fertilizer is not to be recommended. Aside from the expense it is likely to be injurious. Observations indicate that highly fertilized plants are more susceptible to heat; they do not lignify so readily in the fall, and that they are subject to frost danger.

PRACTICE AT FOREST SERVICE NURSERIES.

At the majority of Forest Service nurseries fertilizing has not been accorded much attention because they have been quite recently established, and there has not been opportunity to study this question. At the Bessey Nursery horse manure is invariably mixed with sand and is not used until it has composted thus for a year, during which time it is turned two or three times and watered as often as necessary to prevent heating. It is applied at the rate of from 50 to 120 tons per acre and a crop of cowpeas or soy beans is produced on the area before it is again devoted to nursery purposes. It has been found here that soy beans produce more and larger root nodules than cowpeas. The application of fresh horse manure to the seedbeds just before sowing has proved unsatisfactory, because the undecomposed material made the soil so loose that it dried out very rapidly, resulting in loss of seedlings from drought.

At the Fort Bayard Nursery horse manure is applied at the rate of from 25 to 30 tons per acre, and then frijoles (Mexican beans) are grown for one season on the same area. These have not been plowed under. Crops of frijoles and nursery stock are rotated yearly.

At the Monument Nursery, after the trees are removed in the spring, the area is given a liberal application of well-rotted barnyard manure, which is plowed under to a depth of about 10 inches, and it is then sowed to field peas at the rate of about 75 pounds per acre. When the peas begin to blossom they are plowed under and a second crop sown to be plowed under just before the vines freeze. On the seed-bed area this operation is repeated the following year, but transplant areas are ready for use after one year's treatment.

At the Pilgrim Creek Nursery sheep manure is applied just before spading the beds at the rate of 4½ cubic feet to 144 square feet of seed-bed surface and 45 cubic feet to 700 square feet of transplant-bed surface. The amount for transplant beds is to be increased, as it is not considered sufficient.

At the Garden City Nursery manure and cowpeas were used in rotation with the nursery crops. Sand was also added to the heavy soil and improved it considerably.

Because of the great increase in damping-off which has resulted in some cases from the use of organic fertilizers, especially dried

blood, it is well to warn against the use of any rich organic fertilizers shortly before seed sowing. Ammonium hydroxide when applied at the old Garden City Nursery was followed 3 or 4 weeks later by the almost complete destruction of the seedlings, apparently by damping-off fungi, although it is not absolutely certain that fungi were responsible.

COSTS OF OPERATIONS.

The cost of nursery operations, which are reflected in the costs of stock, are governed by so many conditions that they vary considerably at different nurseries and from year to year. The different elements which effect the cost have been pointed out in the foregoing pages. With the bringing of all nurseries up to a good economic capacity, with a gradual decrease of overhead charges, which in some instances are at present rather high, and with still more improved methods of nursery practice and familiarity with the different species, it is expected that average costs can be considerably reduced in the future. The following represent some of the actual costs of past nursery operations:

Operation.	Cost per thousand.
Growing 1–0 stock	$0.33 to $1.50
Care of 2–0 stock	.06 to .50
Transplanting stock	.77 to 2.04
Care of transplants first year	.18 to 1.03
Digging, packing, and shipping of stock	.74 to 2.43

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